Matti Hovi, Hannele Kytö and Sanna-Kaisa Rautio (eds)

Fire and Forest

The International Forest Fire Symposium in Kajaani 13.-14.11.2007

Metsähallituksen luonnonsuojelujulkaisuja. Sarja A 175
Nature Protection Publications of Metsähallitus. Series A 175

Matti Hovi, Hannele Kytö and Sanna-Kaisa Rautio
Metsähallitus
Natural Heritage Services, Ostrobothnia
Torangintaival 2
93600 Kuusamo
Finland

matti.hovi@metsa.fi
hannele.kyto@metsa.fi
sanna-kaisa.rautio@metsa.fi

Cover Photo: Flames in Elimyssalo, 27.6.2006. Photo: Sanna-Kaisa Rautio.

Översättning: Pimma Åhman.

With the contribution of the LIFE financial instrument of the European community.
Tuotantoa varten on saatu Euroopan yhteisön LIFE-rahoitustukea.

ISSN 1235-6549
ISBN 978-952-446-630-1 (printed)
ISBN 978-952-446-631-8 (pdf)

Edita Prima Oy, Helsinki 2008

Matti Hovi, Hannele Kytö and Sanna-Kaisa Rautio (eds)

Fire and Forest
– The International Forest Fire Symposium in Kajaani 13.-14.11.2007

METLA

METSÄHALLITUS

DOCUMENTATION PAGE

PUBLISHED BY	Metsähallitus	PUBLICATION DATE	20.2.2008
COMMISSIONED BY		DATE OF APPROVAL	
CONFIDENTIALITY	Public	REGISTRATION NO.	
PROTECTED AREA TYPE / CONSERVATION PROGRAMME			
NAME OF SITE			
NATURA 2000 SITE NAME AND CODE			
REGIONAL ORGANISATION	Natural Heritage Services, Ostrobothnia		

AUTHOR(S)	Matti Hovi, Hannele Kytö and Sanna-Kaisa Rautio (eds)
TITLE	Fire and Forest – The International Forest Fire Symposium in Kajaani 13.-14.11.2007

ABSTRACT

Many forests locating in nature protection areas have been earlier used for commercial forestry and are therefore not in a natural state. Habitat restoration aims at speeding up the reversion of the structure and dynamics of habitats towards those typical of natural forests. Restoration is carried out principally in protected areas, and most restoration measures are accomplished only once.

Perhaps the most striking forest restoration method is prescribed fire, which creates disturbance regimes where natural succession dynamics prevails. Prescribed fire produces burnt and charred wood, which is critical for many endangered species.

Fire and Forest symposium, organized by Green Belt Life project, Forest Life project, Finnish Forest Research Institute and Finland's Environmental Administration, brought together leading forest fire experts from Finland, Norway and Sweden to Kajaani in November 2007. The symposium focused on the use of prescribed fire as a management tool within protected areas of Fennoscandian forests. This publication compiles the presentations of the symposium and consists of both practical experiences and research results on restoration. The report gives a glimpse to the fire history of Fennoscandian forests, reveals differences in principles and practices of prescribed fires between countries, and discusses the current situation and future aims of restoration research.

KEYWORDS	forest fires, fire continuum, fire history, forest restoration, prescribed burnings, restoration studies		
OTHER INFORMATION			
SERIES NAME AND NO.	Nature Protection Publications of Metsähallitus. Series A 175		
ISSN	1235-6549	ISBN (BOOK/BOOKLET) ISBN (PDF)	978-952-446-630-1 978-952-446-631-8
NO. OF PAGES	70 pp.	LANGUAGE	English
PUBLISHING CO.	Metsähallitus	PRINTED IN	Edita Prima
DISTRIBUTOR	Metsähallitus, Natural Heritage Services	PRICE	

KUVAILULEHTI

JULKAISIJA	Metsähallitus	JULKAISUAIKA	20.2.2008
TOIMEKSIANTAJA		HYVÄKSYMISPÄIVÄMÄÄRÄ	
LUOTTAMUKSELLISUUS	Julkinen	DIAARINUMERO	
SUOJELUALUETYYPPI/ SUOJELUOHJELMA			
ALUEEN NIMI			
NATURA 2000 -ALUEEN NIMI JA KOODI			
ALUEYKSIKKÖ	Pohjanmaan luontopalvelut		

TEKIJÄ(T)	Matti Hovi, Hannele Kytö ja Sanna-Kaisa Rautio (toim.)
JULKAISUN NIMI	Fire and Forest – Kansainvälinen metsäpalosymposio Kajaanissa 13.–14.11.2007
TIIVISTELMÄ	Monet suojelualueiden metsät ovat aiemmin olleet talouskäytössä, joten vain osa niistä on nykyisin täysin luonnontilaisia. Ennallistaminen on luonnonsuojelualueilla toteutettava, yleensä kertaluontoinen toimenpide, jolla pyritään nopeuttamaan ihmisen muuttaman elinympäristön palautumista kohti luonnontilaa. Poltot ovat ennallistamistoimenpiteistä näyttävimpiä. Suojelualueiden metsiä polttamalla pyritään luomaan alueita, joilla sukkessio lähtee käyntiin alkutilanteesta. Polton seurauksena syntyy runsaasti eriasteisesti palanutta, hiiltynyttä ja vähitellen lahoavaa puuainesta, jota uhanalaiset palolajit tarvitsevat menestyäkseen. Vihreä vyöhyke Life -projektin, Metsä Life -projektin, Metsäntutkimuslaitoksen ja Suomen ympäristökeskuksen järjestämä Fire and Forest -symposio toi vuonna 2007 marraskuiseen Kajaaniin joukon metsäpaloasiantuntijoita Suomesta, Ruotsista ja Norjasta. Kaksipäiväisen symposion aikana perehdyttiin Fennoskandian suojelualueiden metsien ennallistamiseen tulen avulla. Tämä julkaisu kokoaa yhteen Fire and Forest -symposion annin koostuen sekä käytännön kokemuksista että tutkimustuloksista. Julkaisu luo katsauksen metsäpalohistoriaan, maakohtaisiin eroihin ennallistamispolttojen toteutuksessa ja tavoitteissa sekä valottaa ennallistamistutkimuksen tämän hetkistä tilannetta ja tulevaisuuden näkymiä.
AVAINSANAT	metsien ennallistaminen, ennallistamispoltot, ennallistamistutkimus, metsäpalot, palojatkumo, palohistoria
MUUT TIEDOT	

SARJAN NIMI JA NUMERO	Metsähallituksen luonnonsuojelujulkaisuja. Sarja A 175		
ISSN	1235-6549	ISBN (NIDOTTU) ISBN (PDF)	978-952-446-630-1 978-952-446-631-8
SIVUMÄÄRÄ	70 s.	KIELI	englanti
KUSTANTAJA	Metsähallitus	PAINOPAIKKA	Edita Prima Oy
JAKAJA	Metsähallitus, luontopalvelut	HINTA	

PRESENTATIONSBLAD

UTGIVARE	Forststyrelsen	UTGIVNINGSDATUM	20.2.2008
UPPDRAGSGIVARE		DATUM FÖR GODKÄNNANDE	
SEKRETESSGRAD	Offentlig	DIARIENUMMER	
TYP AV SKYDDSOMRÅDE/ SKYDDSPROGRAM			
OMRÅDETS NAMN			
NATURA 2000 -OMRÅDETS NAMN OCH KOD			
REGIONAL ENHET	Österbottens naturtjänster		

FÖRFATTARE	Matti Hovi, Hannele Kytö och Sanna-Kaisa Rautio (red.)
PUBLIKATION	Fire and Forest – Internationellt skogsbrandssymposium i Kajana 13.–14.11.2007
SAMMANDRAG	Många skogar på skyddsområden var tidigare i ekonomibruk, så endast en del av dem befinner sig helt i naturtillstånd. Restaurering består i allmänhet av åtgärder som utförs en gång och målet är att påskynda utvecklingen till naturtillståndet hos en livsmiljö som ändrats genom mänsklig verksamhet. Bränderna hör till de mest anslående restaureringsåtgärderna. Genom bränning av skogar på skyddsområden strävar man efter att bilda områden där successionen startar om från början. Till följd av bränderna uppstår rikligt med död ved, som brunnit och förkolnat i olika grad och som många hotade arter är beroende av. Symposiet Fire and Forest, som arrangerades av Green Belt Life-projektet, Forest Life-projektet, Skogsforskningsinstitutet och Finlands miljöcentral, samlade i november 2007 en skara skogsbrandsexperter från Finland, Sverige och Norge i Kajana. Symposiet räckte två dagar och deltagarna satte sig in i frågor gällande skogsrestaurering genom bränning på skyddsområden i Fennoskandien. Denna publikation presenterar Fire and Forest-symposiets resultat bestående av såväl praktiska erfarenheter som forskningsresultat. Publikationen ger en överblick av skogsbrändernas historia och skillnaderna mellan länderna när det gäller verkställandet av och målen för restaureringsbränderna. Publikationen presenterar också restaureringsforskningens situation i dag och dess framtidsutsikter.
NYCKELORD	restaurering av skogar, restaureringsbränning, restaureringsforskning, skogsbränder, brandkontinuum, brandhistoria
ÖVRIGA UPPGIFTER	
SERIENS NAMN OCH NUMMER	Metsähallituksen luonnonsuojelujulkaisuja. Sarja A 175

ISSN	1235-6549	ISBN (HÄFTAD) ISBN (PDF)	978-952-446-630-1 978-952-446-631-8
SIDANTAL	70 s.	SPRÅK	Engelska
FÖRLAG	Forststyrelsen	TRYCKERI	Edita Prima
DISTRIBUTION	Forststyrelsen, naturtjänster	PRIS	

Preface

Fire is globally considered as one of the most severe threats to protected areas. Authorities and protected area managers share the view that in most ecosystems fires are non-desired guests which means that preventive and suppressive actions against fire demand vast resources annually. Fires are often human-induced, heavy-impact and large-scale disturbances that affect negatively the biodiversity and infrastructure of protected areas.

In some ecosystems, like boreal forests, fire is a natural, stochastic disturbance factor and thus essentially contributes to the ecosystem processes. In landscape level forest fires create diversity in stand structure, thereby increasing the variety of habitats.

Today natural fires are spatially very limited due to effective fire suppression. Since protected areas are commonly small, managers and authorities can not allow uncontrolled wildfires there. Therefore, in forested protected areas prescribed burnings have gradually become increasingly common in Finland, and also elsewhere.

The management of protected areas aims to maintain, safeguard and possibly restore biological diversity. To achieve these goals, managers have to adjust their actions according to information cumulating from monitoring and novel ecological research. As a product of research, managers and scientists can increase their understanding of processes contributing to biodiversity, and mechanisms behind them. The accruing knowledge can consecutively be adopted in future improvements in guidelines and, probably also new viewpoints, to habitat management.

To imitate the natural fire disturbance dynamics in full scale in our small protected areas is not a realistic objective. It is limited not only by the size of areas, but also economic and social restrictions. But, in addition to well-planned and well-located restoration burnings, fire will have a role in maintaining the vital habitat for species dependent on burned wood. In these cases, prescribe burnings may be sharply specified in their purposes.

One of the objectives of EU's Life Nature funded Green Belt Life project, running in Kainuu and Koillismaa regions during 2004-2008, has been to increase awareness related to forest fires and prescribed burning. This publication compiles the presentations of the Fire and Forest symposium held in November 2007 in Kajaani. The publication is a versatile cross-section of both scientific research and managers' views.

Kuusamo, 1.2.2008

Matti Hovi

Esipuhe

Tulta pidetään yhtenä merkittävimmistä maailman luonnonsuojelualueita uhkaavista vaaroista. Maastopalot ovat useimmissa ekosysteemeissä viranomaisten ja suojelualueiden hoitajien käsityksen mukaan ei-toivottuja vieraita, ja niiden torjuntaan käytetään vuosittain valtavasti resursseja. Palot ovat usein ihmisperäisiä, voimakkaita häiriöitä, joiden vaikutus suojeltujen kohteiden monimuotoisuuteen on haitallinen.

Eräissä ekosysteemeissä, kuten boreaalisissa metsissä, tuli on luontainen stokastinen häiriötekijä ja siten osa ekosysteemin prosesseja. Maisematasolla metsäpalot luovat puustoon vaihtelevuutta ja lisäävät siten elinympäristöjen kirjoa.

Nykyään luontaiset metsäpalot ovat yhä pienialaisempia tehokkaan palontorjunnan seurauksena. Koska suojelualueet ovat yleensä pinta-alaltaan pieniä, ei niissä voida sallia hallitsemattomia metsäpaloja. Niinpä metsäisiin suojelualueisiin kohdennettu suunnitelmallinen ja kontrolloitu poltto on yleistynyt sekä Suomessa että maailmalla.

Suojelualueiden luonnonhoidon ja ennallistamisen tavoitteena on biologisen monimuotoisuuden ylläpitäminen, turvaaminen ja mahdollisesti myös palauttaminen. Jotta toimet todella johtaisivat näihin tavoitteisiin, tarvitaan sekä toimien vaikutusten seurantaa että uutta tieteellistä perustutkimusta. Tutkimuksen keinoin voidaan luoda käsitys monimuotoisuutta ylläpitävistä prosesseista sekä niihin vaikuttavista mekanismeista. Karttuva tietämys voidaan omaksua suojelualueen hoidossa alati täsmentyvinä ohjeina ja tarvittaessa uusina näkökulmina.

Metsien luontaisen häiriödynamiikan eksakti jäljittely hallituin hoitokeinoin ei liene realistista pienillä suojelualueillamme. Sitä rajoittavat alueiden koon lisäksi myös taloudelliset ja sosiaaliset tekijät. Kohdennetun ennallistamisen lisäksi tulella on jatkossakin tehtävänsä palaneesta puusta riippuvan lajiston elinympäristöjen hoidossa. Tällöin voidaan puhua jonkinlaisesta ”täsmähoidosta”.

Kainuussa ja Koillismaalla vuosina 2004–2008 toimineen, Euroopan unionin Life Luonto -rahaston tukeman Vihreä vyöhyke Life -hankkeen eräänä tavoitteena on ollut lisätä metsäpaloihin ja metsien tarkoitukselliseen polttamiseen liittyvää tietoisuutta. Tässä julkaisussa kiteytyy marraskuussa 2007 järjestetyn kansainvälisen Fire and Forest -symposion anti. Julkaisu on monipuolinen läpileikkaus sekä aihepiiriin liittyvästä tutkimuksesta että käytännön hoitotyötä tekevien ja kehittävien tahojen näkemyksistä.

Kuusamossa 1.2.2008

Matti Hovi

Contents

1 Fire Continuums and Their Restoration in Fennoscandia

Jari Kouki

Faculty of Forest Sciences, University of Joensuu, PO Box 111, 80101 Joensuu, Finland

1.1 Introduction

Fires are often regarded as the main disturbance factor in boreal forests both in Eurasia and North America (e.g. Heinselman 1973, Zackrisson 1977, Van Wagner 1978, Bonan & Shugart 1989, Clark 1990, Bergeron 1991, Johnson 1992, Danserau & Bergeron 1993, Niklasson & Drakenberg 2001, Bergeron et al. 2002). In natural boreal forests, repeated fires maintain mosaic-like and patchy landscape structure where stand characteristics vary from site to site and from time to time. Such natural landscape dynamics and patterns are rarely maintained nowadays any more in boreal regions. In different parts of the boreal zone fires may have either increased due to human activites (Yaroshenko et al. 2001, Achard et al. 2006) or decreased if fire suppression is efficient (Zackrisson 1977, Niklasson & Granström 2000). Fennoscandia – Norway, Sweden, and Finland – are prime examples of boreal areas where fire suppression has been very effective and almost completely removed fires. A few scattered fire sites that currently occur annually are typically salvage logged and regenerated artificially after the fire so that ecological consequences of fires disappear from the following successional stages (Kouki et al. 2001). Thus, the multitude of ecological consequences both at the stand and landscape level have vanished during the past one hundred years. These changes have had a major influence on ecological properties of forests.

Fire suppression is not restricted only to the managed production forests but fires are eliminated also from the forest conservation areas. As a consequence of this, the forest-dwelling species that are dependent on fires or on the ecological patterns and forest structures created by fires may not find suitable habitats from the protected forests either. These observations have led to major efforts in Fennoscandia recently that aim to restore fire in these ecosystems. Besides in the protected forests, the use of prescribed fire as a site preparation method in managed forests have been emphasised recently.

However, establishing and re-introducing forest fires in Fennoscandia is complicated by several factors and problems that are scientifically only superficially addressed so far. Key questions are related on three general issues: First, what would be the natural fire pattern that should be followed in the restoration activities? Second, what are the detailed ecological consequences of restoration fires, in particular in relation to providing habitat for threatened and declined species? Third, how should the re-introduction of fires be done spatially and regionally, or, are there marked differences in the payoffs gained from the use of fires in different regions?

1.2 Spatial and temporal patterns of fires in Fennoscandia

Generally speaking, the Fennoscandian region has experienced three consecutive phases in the recent occurrence of forest fires: (1) the period of natural fires with low level of human influence, (2) the period of clearly increased fire frequencies, mostly due to widely practised slash-and-burn cultivation, and (3) the period of effective fire suppression (e.g. Zackrisson 1977, Pitkänen & Huttunen 1999, Niklasson & Granström 2000, Carcaillet et al. 2007). Although this general pattern seems to hold in many parts of Fennoscandia, there are notable regional and temporal exceptions, too. Different site types or geographically distant areas may not show exactly the similar pattern. Furthermore, this general pattern does not account for the differences in detailed characteristics of fires. Most notably, it does not pay attention to variations in fire intensity or severity that has remarkable ecological consequences.

From the viewpoint of restoring natural fire continuums, the first period is perhaps the most interesting albeit the latter periods are also important when re-introducing fires because also the slash-and-burn period may have maintained some of the ecological continuums.

It is very well documented that the slash-and-burn period differed remarkably both from the previous as well as from the fire suppression period (Lehtonen et al. 1996, Lehtonen & Huttunen 1997, Pitkänen & Huttunen 1999, Niklasson & Granström 2000, Pitkänen et al. 2002). The slash-and-burn was practised in large areas. For example, in Finland it was commonly practised everywhere southwards from the Arctic Circle, except near the western shoreline where trees have been removed for tar production previously (Heikinheimo 1915). During this period fire frequencies increased and fire intervals were shortened only to 30-40 years in the most productive forests. Spatially, single fires covered much smaller areas than before the slash-and-burn period. It has been discussed that the lack of fuel was one of the main reason for small size of fires, especially towards the end of 1800s (Niklasson & Granström 2000). Since forests were repeatedly burned there simply was not anymore enough biomass for the fire to spread in the landscape.

Only few studies have been able to address the fire frequencies that occurred before the slash-and-burn period. Main challenge is that dendrochronological cross-dating is not readily possible for the time periods AD 1400s and before because of the lack of suitable sample trees, i.e. the trees that lived on those times have already decayed and mostly disappeared from the forests. Analyses based on pollen and charcoal sediment varves provide an alternative way to assess pre-1500s fires. Although sediment analyses do not give detailed results on spatial aspects such as location or size of the burned areas, they may nevertheless provide fine insights into temporal patterns.

Charcoal analyses from eastern Finland, for example, have shown that average fire intervals were around 100 years before slash-and-burn cultivation, i.e. almost double of that reported from dendrochronological studies (1500-1800) (Pitkänen & Huttunen 1999, Pitkänen & Grönlund 2001, Pitkänen et al. 2003). What is even more important, pollen analyses can also shed some light on fire severities. This is based on the idea that the two major tree species – the Scots pine and the Norwegian spruce – have different abilities to survive fires. Pines can easily survive mild surface fires once they reach diameter of about 15-20 cm, whereas spruce is much more vulnerable to all fires. As a consequence of these biological differences between the species, a severe and intensive fire should kill both spruce and pine trees whereas a mild surface fire at the ground layer should reduce only the amount of spruce pollen in the corresponing dated varves. Based on these ideas, it has been estimated that perhaps only every second fire that occurred before 1500s was a canopy-fire and stand-replacing fire (Pitkänen & Huttunen 1999). On average, this implies that a stand typically reached 200 years before it was substantially affected by fires. Many fires have been relatively mild in their effects.

The role that humans have had on past fire frequencies before slash-and-burn period has remained somewhat unclear. It is quite possible that also a low human population density may influence fire patterns. However, a recent study shows that small human populations did not have a considerable influence on fire patterns in northern Sweden (Carcaillet et al. 2007). Thus, it may be safe to assume that studies addressing fire frequencies and intensities before slash-and-burn period may indeed show natural patterns that are negligibly affected by humans.

A more obvious pattern in the Fennoscandian fires is that they practically diappeared after around AD 1900. Slash-and-burn cultivation was ceased, partly because the value of timber became higher when used for sawlogs first, and for pulp and paper later on during the 1900s.

1.3 Ecological effects of restoring fires

The disappearance of fires has naturally eliminated also all the ecological consequences that fires have had on forest ecosystems. In particular, many species that strive in natural, disturbance- and fire-driven forests have disappeared or their populations have decreased.

Although the general importance of fire for many forest-dwelling species is widely acknowledged (Wikars 1994, Kouki et al. 2001), only a few studies have experimentally addressed the issues related to fire and clear-cuts as disturbance factors and the occurrence of rare and threatened species. Such studies are badly needed also when restoration burnings are planned on protected areas.

Studies based on large-scale experimental approaches have shown that burning and prescribed fires can have a clear positive effect on the occurrence of several threatened species (Hyvärinen et al. 2005, Hyvärinen et al. 2006, Toivanen & Kotiaho 2007). Beetles have received most of the attention so far, partly because they respond rapidly to fires and also because there are quite a few species known to be associated with fires. A study done in pine forests in eastern Finland has shown that burning a forest may bring 3-4 threatened beetle species more on the burned sites than on the corresponding unburned sites already within a few years after the fire (Hyvärinen et al. 2005, Hyvärinen et al. 2006). This difference is likely to increase due to time as some of the effects of fire on trees accumulate slowly over longer periods, such as slow dying of the trees injured by the fire.

A corresponding study from the spruce forests in southern Finland has produced equally clear results. Burned spruce forests harboured about 0-1 more threatened species than unburned forests (Toivanen & Kotiaho 2007). The slight difference compared with the pine forests is likely due to smaller sample in the latter study rather than an indication of the real difference in the fire effects.

Both these studies show that controlled burning of forests is an effective tool to enhance and increase habitat for several threatened species. This provides a solid background for the efforts that aim at restoring the lost fire continuums. Even if the fire continuums have disappeared, many species are still able to re-establish themselves if only suitable habitat is provided, for example, by careful management.

1.4 Spatial and regional aspects on restoring fire continuums

The third main issue on restoring fire continuums is related to regional and spatio-temporal aspects of re-introducing fires. Since the ecological history and the temporal patterns of fires may differ in differing parts of the Fennoscandia, it is tempting to assume that in some regions the colonising species pool is still more diverse. For example, fires – both natural and slash-and-burn – in eastern Finland were probably more common than in western Finland towards the end of 1800s, and still are at the Russian side of the border. This may have created a situation where fire-dependent or fire-favoured species may have better possibilities to colonise burned areas in eastern parts of the country as compared with the western areas where fire continuums disappeared longer time ago.

This was followed and monitored in the Metsä-Life programme (Kouki, Hyvärinen, Similä, unpublished data) that offered unique possibilities to investigate the ecological consequences and the payoffs from restoration burnings. Nine areas were selected for the monitoring. Initially these sites were previously managed pine forests that are currently located inside the protected areas. The stands were rather dense, comprising mostly of pine with average dbh 15 cm (Fig. 1). Thus, they were typical in the sense that many Finn-

Figure 1. Burned site at Ruunaa nature reserve. Photo taken immediately after fire. Photo: Maarit Similä.

ish protected areas include comparable stands of which the level of naturalness is rather poor. The monitored stands were burned and their beetle assemblages were sampled with window traps during one month after the burnings.

Several pyrophilous, threatened and threatened pyrophilous species (including beetles and flatbugs) were recorded in the sites already within this short monitoring period. What was notable, in particular, was that there was a clear difference between the restored areas that were located in the eastern part and in the western part (Fig. 2). On average, restored forests in the east – that are probably less isolated from the source areas or still maintain species – number of pyrophilous species was about 5 species more per stand. Similar results were obtained also when all threatened species (difference: about 8 species more in the east) or pyrophilous threatened species (difference: about 3 species more in the east) were compared.

These results show that restoration burnings bring positive effects everywhere in the southern Finland in terms of the occurrence of threatened and pyrophilous species. However, there is also a marked regional effect so that restoration in the eastern parts of the country seems to have much higher positive effect on species, at least in the short run. Thus, the immediate ecological payoffs of applying fire in the management of conservation areas seems to be higher in eastern than in the western Finland.

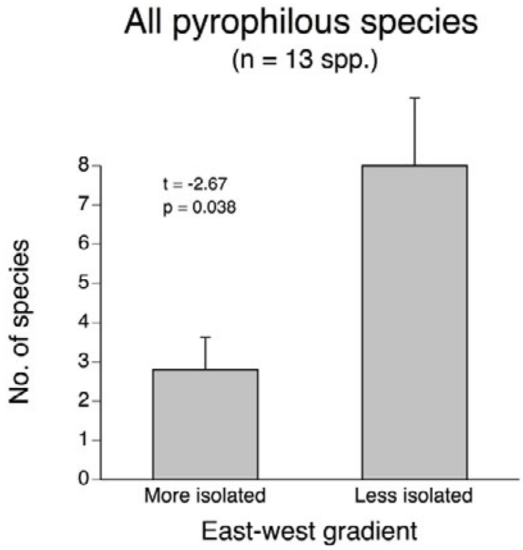

Figure 2. Average (mean ± S.E.) number of pyrophilous invertebrate species (beetles and flatbugs) observed in burned areas in eastern ("less isolated") and western ("more isolated") parts of southern Finland during one month after restoration burnings. Westerns sites are supposedly more isolated from the species' source areas than the eastern sites.

1.5 Conclusions

Three conclusions arise from this overview:

First, there is a wealth of evidence that fires used to be the major disturbance factor in the Fennoscandian boreal forests before 1900s and that fires have almost completely disappeared since then. The historical occurrence of fires shows several regional, spatial and temporal patterns in their occurrence which makes it somewhat hard to define natural fire patterns in this region (see also Rouvinen & Kouki 2008). Consequently, restoring fire continuums requires further explorations on detailed patterns of past fires as well as their main effects on forest ecosystems.

Second, even if the detailed guidelines to effectively plan and execute restoration fires are largely missing, the positive effects of fires on forest biodiversity and on the conservation of several threatened forest-dwelling species is obvious. This has been verified, for example, by the recent large-scale experimental approaches (studies from Finland include Hyvärinen et al. 2005, Hyvärinen et al. 2006, Toivanen & Kotiaho 2007, Vanha-Majamaa et al. 2007).

Third, there are clear regional effects that modify the ecological consequences of restorative fires. These differences may reflect the historical patterns of forest management and the past occurrence of fires. Areas that remained outside the current intensive forestry several decades at the beginning of 1900s (Lihtonen 1949) and where fires were common still at the end of 1800s (Heikinheimo 1915), seem to give highest payoffs. That is, if a similar forest stand is burned in these regions and in regions outside these hotspot areas, the benefits to biodiversity are higher in the former group. This emphasises the need to plan restorative fires so that also the regional differences are taken into account. It might, for example, provide best results if the restorative burnings are slowly advanced from east to west which would allow the fire-associated species to spread and expand their distributional ranges accordingly.

References

Achard, F., Mollicone, D., Stibig, H. J., Aksenov, D., Laestadius, L., Li, Z. Y., Popatov, P. & Yaroshenko, A. 2006: Areas of rapid forest-cover change in boreal Eurasia. – Forest Ecology and Management 237: 322-334.

Bergeron, Y. 1991: The influence of island and mainland lakeshore landscapes on boreal forest-fire regimes. – Ecology 72: 1980-1992.

— , Leduc, A., Harvey, B. D. & Gauthier, S. 2002: Natural fire regime: A guide for sustainable management of the Canadian boreal forest. – Silva Fennica 36: 81-95.

Bonan, G. B. & Shugart, H. H. 1989: Environmental factors and ecological processes in boreal forests. – Annual Review of Ecology and Systematics 20: 1-28.

Carcaillet, C., Bergman, I., Delorme, S., Hornberg, G. & Zackrisson, O. 2007: Long-term fire frequency not linked to prehistoric occupations in Northern Swedish boreal forest. – Ecology 88: 465-477.

Clark, J. S. 1990: Fire and climate change during the last 750 yr in northwestern Minnesota. – Ecological Monographs 60: 135-159.

Danserau, P. R. & Bergeron, Y. 1993: Fire history in the southern boreal forest of northwestern Quebec. – Canadian Journal of Forest Research 23: 25-32.

Heikinheimo, O. 1915: Kaskiviljelyksen vaikutus Suomen metsiin. – Acta Forestalia Fennica 4: 1-264.

Heinselman, M. L. 1973: Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. – Quaternary Research 3: 329-382.

Hyvärinen, E., Kouki, J. & Martikainen, P. 2006: Fire and green-tree retention in conservation of red-listed and rare deadwood-dependent beetles in Finnish boreal forests. – Conservation Biology 20: 1711-1719.

— , Kouki, J., Martikainen, P. & Lappalainen, H. 2005: Short-term effects of controlled burning and green-tree retention on beetle (Coleoptera) assemblages in managed boreal forests. – Forest Ecology and Management 212: 315-332.

Johnson, E. A. 1992: Fire and vegetation dynamics: Studies from the North American boreal forest. – Cambridge University Press, Cambridge. 125 pp.

Kouki, J., Löfman, S., Martikainen, P., Rouvinen, S. & Uotila, A. 2001: Forest fragmentation in Fennoscandia: Linking habitat requirements of wood-associated threatened species to landscape and habitat changes. – Scandinavian Journal of Forest Research Suppl. 3: 27-37.

Lehtonen, H. & Huttunen, P. 1997: History of forest fires in eastern Finland from the fifteenth century AD – the possible effects of slash-and-burn cultivation. – The Holocene 7: 223-228.

— , Huttunen, P. & Zetterberg, P. 1996: Influence of man on forest fire frequency in North Karelia, Finland, as evidenced by fire scars on Scots pines. – Annales Botanici Fennici 33: 257-263.

Lihtonen, V. 1949: Piirteitä valtion metsätaloudesta. – Silva Fennica 66: 1-46.

Niklasson, M. & Drakenberg, B. 2001: A 600-year tree-ring fire history from Norra Kvills National Park, southern Sweden: implications for conservation strategies in the hemiboreal zone. – Biological Conservation 101: 63-71.

— & Granström, A. 2000: Numbers and sizes of fires: long-term spatially explicit fire history in a Swedish boreal landscape. – Ecology 81: 1484-1499.

Pitkänen, A. & Grönlund, E. 2001: A 600-year forest fire record in a varved lake sediment (Ristijarvi, Northern Karelia, Eastern Finland). – Annales Botanici Fennici 38: 63-73.

Pitkänen, A. & Huttunen, P. 1999: A 1300-year forest-fire history at a site in eastern Finland based on charcoal and pollen records in laminated lake sediment. – The Holocene 9: 311-320.

— , Huttunen, P., Jungner, H. & Tolonen, K. 2002: A 10 000 year local forest fire history in a dry heath forest site in eastern Finland, reconstructed from charcoal layer records of a small mire. – Canadian Journal of Forest Research 32: 1875-1880.

— , Huttunen, P., Jungner, H., Meriläinen, J. & Tolonen, K. 2003: Holocene fire history of middle boreal pine forest sites in eastern Finland. – Annales Botanici Fennici 40: 15-33.

Rouvinen, S. & Kouki, J. 2008: The natural Northern European boreal forests: Unifying the concepts, terminologies, and their application. – Silva Fennica 42: 135-146.

Toivanen, T. & Kotiaho, J. 2007: Mimicking natural disturbances of boreal forests: the effects of controlled burning and creating dead wood on beetle diversity. – Biodiversity and Conservation 16: 3193-3211.

Van Wagner, C. E. 1978: Age class distribution and the forest fire cycle. – Canadian Journal of Forest Research 8: 220-227.

Vanha-Majamaa, I., Lilja, S., Ryoma, R., Kotiaho, J. S., Laaka-Lindberg, S., Lindberg, H., Puttonen, P., Tamminen, P., Toivanen, T. & Kuuluvainen, T. 2007: Rehabilitating boreal forest structure and species composition in Finland through logging, dead wood creation and fire: The EVO experiment. – Forest Ecology and Management 250: 77-88.

Wikars, L.-O. 1994: Effects of fire and ecology of fire-adapted insects. – University of Uppsala, Department of Zoology, Uppsala. 22 pp.

Yaroshenko, A., Potapov, P. & Turubanova, S. 2001: The last intact forest landscapes of Northern European Russia. – Greenpeace Russia. 75 pp.

Zackrisson, O. 1977: Influence of forest fires on the North Swedish boreal forest. – Oikos 29: 22-32.

2 Human Influence on Fennoscandian Fire History

Tuomo Wallenius

Finnish Forest Research Institute, Vantaa Research Unit, P.O. Box 18, 01301 Vantaa, Finland

Annually burnt areas in Fennoscandian forests are currently minuscule. In the past five hundred years fire cycles ranged from 20 years to several hundred years depending on the region and forest type. In general, southern forests burned more often than northern forests and pine forests more frequently than spruce forests. In most of the Fennoscandia number of fires and annually burnt area sharply declined in 1860s and 1870s. In southernmost Sweden and Norway the decrease took place already during 1750-1780.

The decrease of fires is generally attributed to effective fire suppression, i.e. fire prevention and the active extinguishing of fires. However, it has seldom been considered a) what is the actual contribution of more careful handling with fire and b) what is actually the effect of putting out ongoing fires ignited by lightning strikes. Here I pose three factors, which suggest that most of the past fires (measured in terms of number of fires as well as burned area) were caused by humans and that the decline in fires was due to more careful handling with fire; and possibly due to extinguishing of human caused fires in their early stages.

First of all, the contemporaries of frequent fires during the 19th century reported that the vast majority of forest fires were caused by humans. Lightning strikes were considered as an insignificant reason for fires. Secondly, current densities of lightning ignitions are miniscule, in concordance with the observations of the early foresters. It seems unlikely that lightning ignitions could produce the often mentioned "100-year natural fire cycle" for any larger area. In Finland it would require that the average fire size would be about 2,000 hectares. Third reason, which suggests that humans were the dominant cause of past fires, is the dramatic decline in fires in 18th and early 19th centuries. Fires almost ended also in many remote places where detection of lightning fires, early attack or effective extinguishing of larger fires were certainly difficult or impossible due to lack of fire fighters, roads and motorized equipment.

In conclusion, humans have likely caused majority of the fires in the past. Natural fire cycles are probably considerably longer than previously thought. This should be taken into account in attempts to reintroduce fire into forest in restoration practices.

3 Use of Fire in Forestry on Privately Owned Forests in Finland

Lauri Saaristo

Forestry Development Centre Tapio, Soidinkuja 4, 00700 Helsinki, Finland

Use of fire on private forests in Finland has traditionally been prescribed burning for regeneration purposes. Up to the middle of 1960's, prescribed burning was done annually on some 5,000-10,000 hectares of private forests. Since then, the amounts have dwindled. During the last years, the prescribed burning area has covered only few hundreds of hectares per year (Fig. 1). Still, the culture of prescribed burning has remained in some parts of the land for certain reasons: (1) some forestry professionals have the knowledge and a willingness to do burnings, (2) a small amount of burnings are demanded in the forest certification criteria and (3) the government gives support for prescribed burning.

Prescribed burning is still a good and recommended method in forest regeneration, but it is quite expensive and can be replaced by other methods, mainly by mechanical land preparation. Ecological research has revealed many positive biodiversity aspects that the use of fire can create in protected areas and also in managed forests. Biodiversity and especially the threatened species living on burned wood have become the major reason for the government to give support for prescribed burnings.

This shows clearly in the recent legislation, where a new term "biodiversity supporting prescribed burnings" is introduced. To increase the area of prescribed burnings, modifications are planned for its state funding from 2008 onwards. The idea is that in the future all costs of prescribed burnings are to be reimbursed for the forest owner. This makes it possible to fund the use of fire for biodiversity management in private forests. The ministry of forestry and agriculture has set the challenge to develop prescribed burnings to result better conditions for species that live on burned forests.

The development work, conducted by the forestry development centre Tapio, have recognized, that the main ecological factors of the prescribed burning area are the number and quality of the retention trees left in the clear cut, vegetation type, the size of the burned area, the intensity of the fire and the location of the burned area in relation to other recently burned forests.

The team reforming the subsidies for prescribed burning suggests that financing could be granted for three kinds of activities. If the aim was forest improvement, burning would be subsidized if enough retention trees were left on the felled area. Enough means, based on scientific studies, at least ten cubic meters of mainly stout trees. Prescribed burnings in nutrient-poor areas, where the activity can have no forest management aim, could be subsidized as well. The burning of several retention tree groups in a certain region would also get financing.

In the future, these activities should be more commonly put into practise in private forests after a regeneration felling. The use of fire as a tool in management of some valuable habitat or in ecological restoration should require a more careful nature management planning to get financial support. Also it would be important, that subsidies could be paid for a private forest owner, who is willing to protect a forest after a natural fire.

One question is, that how the spatial aggregation of the species living in burned forests could be taken in the considerations, when developing the use of fire in private forests. Prescribed burnings in private forests could have a major role in maintaining those species in some areas of Finland. Still, in private forestry, the decisions of how and where to burn are made by the forest owners and managers (Fig. 1).

The use of fire in all the forests, regardless of the status or the owner, is forming the landscape for the species living in burned forests. Co-operation of private and governmental sector is needed to estimate the best solutions to manage the biodiversity of burned forests, using the fire continuity-areas concept introduced by Metsähallitus.

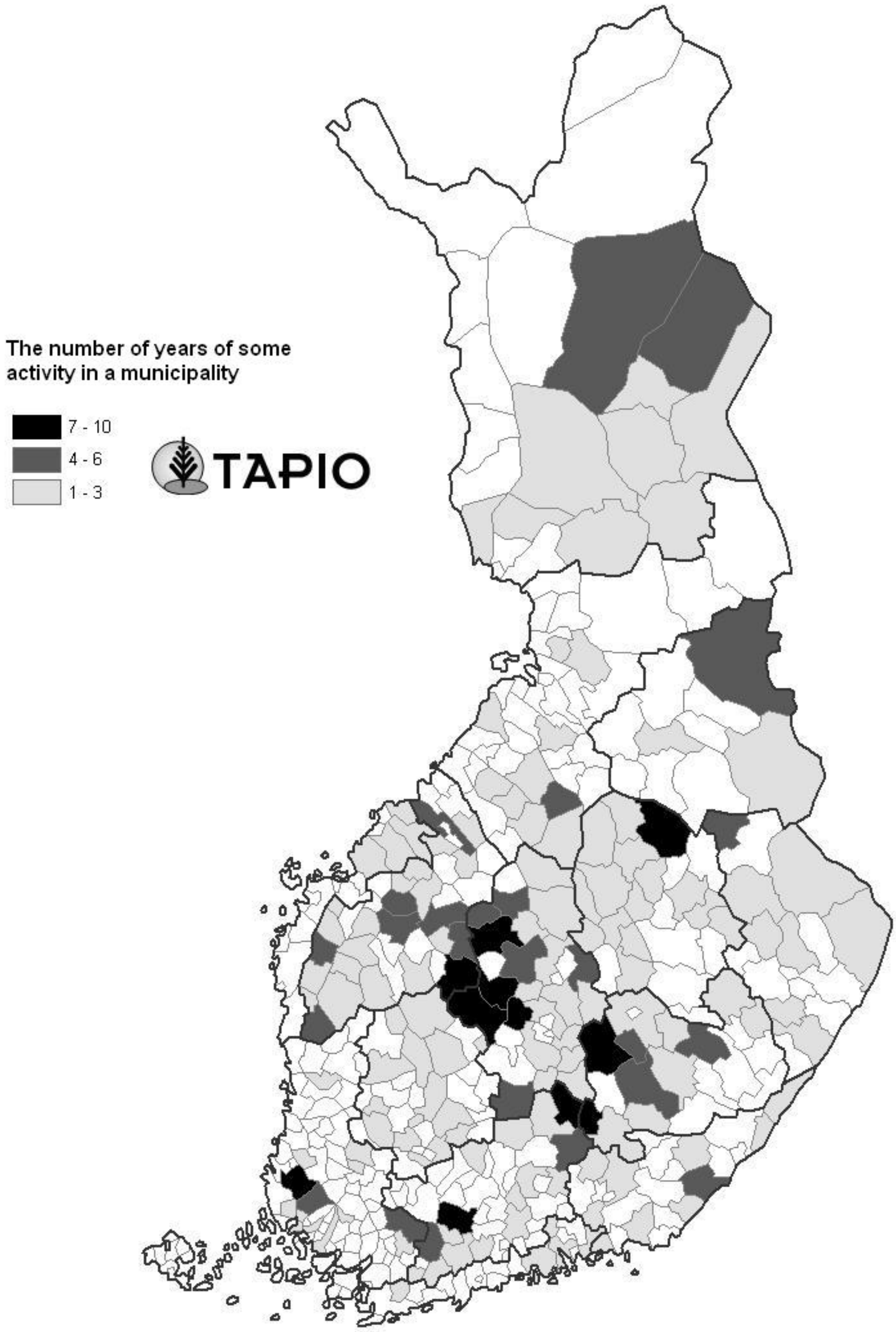

Figure 1. Prescribed burnings in private forests 1997-2006. Source: Forestry Development Centre Tapio.

4 Fire Implications in Restoration Ecology

Timo Kuuluvainen

University of Helsinki, Department of Forest Ecology, PO Box 27, 00014 University of Helsinki, Finland

In Finland the utilization of forests has been and continues to be intensive. Silvicultural treatments such as planting and thinning are widely used to create homogeneous even-aged stands. The dominant harvesting method is clear cutting, currently with retention trees left in groups. The cutting rotation is ca. 100 years which has traditionally been considered to represent the natural fire cycle. New research results indicate that natural fire rotations have varied notably within the country and have been longer than hitherto assumed, especially in the north up to several hundreds of years. In pine dominated forests the fire regimes have been characterized by mixed severity fires, where low- or medium-severity fires are dominant. In spruce forests, where fires occur less frequently, stand-replacement has been more common. In addition and in the absence of fire, secondary disturbances in the form of mortality of individual trees and small groups of trees due to various causes plays a ubiquitous role in the natural forest dynamics. The forest habitat structures and variability created by natural fire and non-fire disturbance dynamics differ fundamentally from forest structures created by current management disturbances characterized by clear cut harvesting. Restoring some of the natural forest habitat structures requires a shift from the dominance of clear cutting toward a range of partial harvesting methods, which better maintain structural features important for biodiversity than current management methods.

5 Fire as a Management Tool in Protected Areas: Principles and Practices in Finland

Esko Hyvärinen

Metsähallitus, Natural Heritage Services, Southern Finland, P.O.Box 36, 80101 Jyväskylä, Finland

From the beginning of the 20th century, natural disturbances have largely been replaced by stand-replacing disturbances of human origin, such as intensive forestry. Natural disturbances of high intensity, such as forest fires, create habitats with extensive biological legacies from the pre-disturbance forest, such as high quantities of dead wood. Numbers of forest-dwelling species are adapted to benefit from these environments. Due to the current land use in Fennoscandia, in particular, it is clear that the natural disturbance regimes cannot be restored on a large scale. In order to create important structural properties in the forest landscape and to maintain species dependent on burned areas we have to use controlled burning as a management tool also in reserves.

The significance of forest fires for forest-dwelling biota has been shown in several studies. Relationship between beetles (Coleoptera), dead wood and forest fires has been studied quite intensively in recent years in Finland, and it has been shown that not only the pyrophilous species but also hundreds of other species, in particular those dependent on dead wood, benefit from burning. Many of these species are red-listed in Finland. Polypores seem to benefit from burning, also, but their responses need longer term monitoring.

Currently controlled burning is used primarily as a means of forest restoration in reserves in Finland. Forests that are burned are usually rather young and previously used for timber production. Burning is used to initiate natural forest succession and to create habitats for pyrophilous species. By the end of 2006, 880 ha of forest was burned in Metsähallitus' reserves, of which 559 ha after the year 2003. This increase is largely due to increased resources for forest restoration through EU Life projects. The importance of burning for forest-dwelling biota is now widely acknowledged, however, and Metsähallitus' Natural Heritage Services has a target to burn 200 ha of forest annually in Finland.

In 2003 the working group on restoration proposed that there should be a network of fire continuum areas based on state-owned reserves (Ennallistamistyöryhmä 2003). The network was planned by Metsähallitus in 2004 and the plan was updated and published this year (Päivinen & Aapala 2007). The network of fire continuum areas include 52 areas from South to North of Finland (Fig. 1). The areas were chosen based

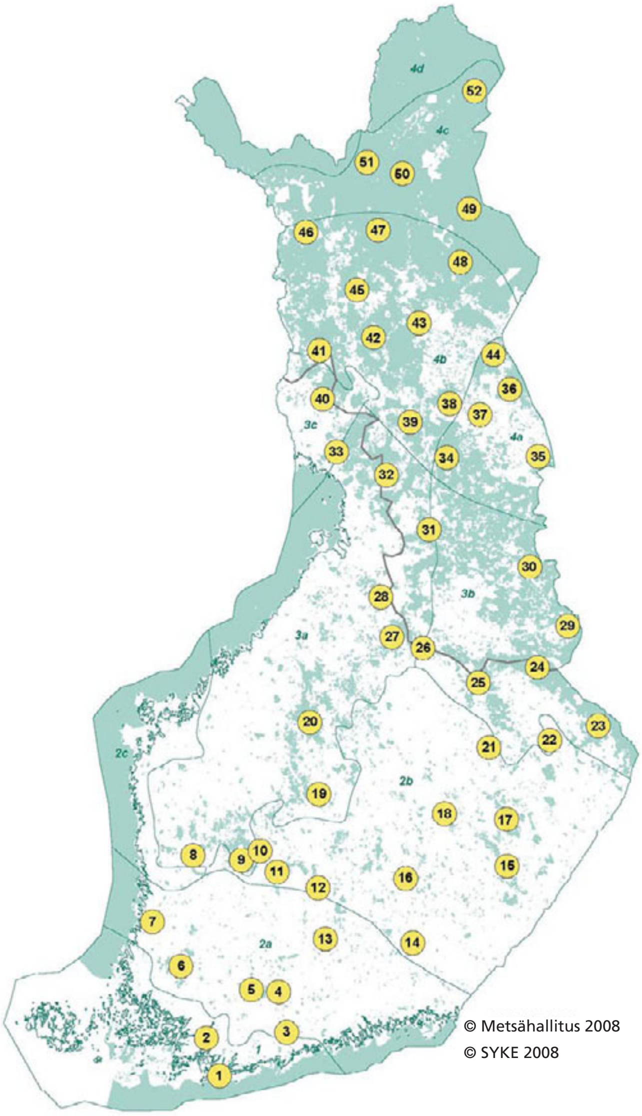

Figure 1. Location of fire continuum areas in Finland. State-owned areas are coloured in the map.

on previous fire history, known occurrences of pyrophilous species and geographical location of areas in order to achieve good coverage over Finland and to include the most important areas for conservation of pyrophilous species. The desirable fire frequency vary between one and five years depending on the area. In general, higher frequences are maintained in southern Finland and in the north burning is implemented less often. The frequency here does not refer to burning of the same site again but to burning of different sites within the same fire continuum area. If natural and accidental fires occur close to these areas the planned controlled burnings will be postponed. The formation of fire continuums is supported in managed forests surrounding reserves. There burnings are implemented with some tree retention by Forestry of Metsähallitus.

In North and East Finland older forests are planned to be burned, too, in addition to those normally burned as a part of forest restoration. This is done not only to create fire continuums and habitats for pyrophilous species but to improve the quality of forests and to mimic natural processes in these areas. Species inventories are done before burning to avoid harm for important species. The effects of burning on biota is monitored after burning. The following criteria are used in choosing the old-growth forest sites to be burned and in implementation of burning:

– the representativeness of a site as a natural forest is low
– the volume of dead wood is lower than average within the reserve
– signs of previous forest fires are found or the forest site type is such that gets easily burned
– the site should have natural borders so that making of artificial fire breaks can be avoided
– the intensity of fire is maintained natural so that no trees are cut to increase it
– a single fire must not exceed 20 ha in North Finland and 10 ha in East Finland
– at most 50 ha are burned annually in North Finland and 20 ha in East Finland.

References

Ennallistamistyöryhmä 2003: Ennallistaminen suojelualueilla: ennallistamistyöryhmän mietintö. (Summary: Restoration in protected areas: report by the working group on forest restoration). – Suomen ympäristö 618. 220 pp.

Päivinen, J. & Aapala, K. (eds.) 2007: Metsien ja soiden ennallistamisen seurantaohje. [in Finnish] – Metsähallituksen luonnonsuojelujulkaisuja. Sarja B 83. 98 pp.

6 Principles and Practices in Sweden

Tomas Rydkvist

County Administrative Board of Västernorrland, Pumpbacksgatan 19, 871 86 Härnösand, Sweden

Actually there are no "Principles and Practices" in Sweden, when it comes to prescribed fire, at least not on a national level. There are some counties that have started to write a plan on how to use fire in protected areas within their jurisdiction. The county of Västernorrland started the work with the "County Burn Plan" (CBP) in December 2007. This plan should be divided into two different parts but that's not yet decided.

Part one must include a description of the fire history in the county of Västernorrland. And it should include a discussion over the reasons as well as the present demand for using fire in protected areas. This part should also include rules how we must act when we are burning in state-owned areas. There should be a description about skills needed for burning forests. There should be a description of the safety rules and other regulations that must be followed. Part one is also the document that needs to be signed by the county governor in order to become a guideline in the use of fire in protected areas.

Part two is the more practical part of the County Burn Plan and should contain a list of all the protected areas and the planned ones. This list should then describe whether we can or cannot use fire, depending on the present and/or predicted future nature values. It should indicate those areas where burning is banned. The list should also include all the protected areas where fire is needed as a management tool in order to preserve and maintain biological diversity. It should also contain the individual planned fire fields so that people can actually see where fire will be used and how large each burn will be. They can also see a map of each planned area with the borders and how we have planned the security.

In Sweden most of the forest burning is conducted by certified forest companies. The majority of the Swedish forest companies are certified according to Forest Stewardship Council (FSC). Thus they are obliged to burn five percent of the annually logged area on dry and mesic ground during a five year period. The total area burned by forest companies mounts up to approximate 2,000-3,000 hectares per year. Most of that area has a low biological diversity, since they most often burn clear-cut areas with few retention trees. Also they often burn under very secure conditions, when the moisture content is high. If they have an unlogged patch of forest out on the cut block, they will probably not get any affect at all in that patch due to wet conditions. Sometimes they even use mechanical scarification and plantation after burn, which is a proof of prescribed fire under very bad conditions. It is also a proof of bad planning and judgment since it is waste of money.

The different counties burn only between 25-200 hectares annually (Fig. 1). Most of the burned areas are within nature reserves and

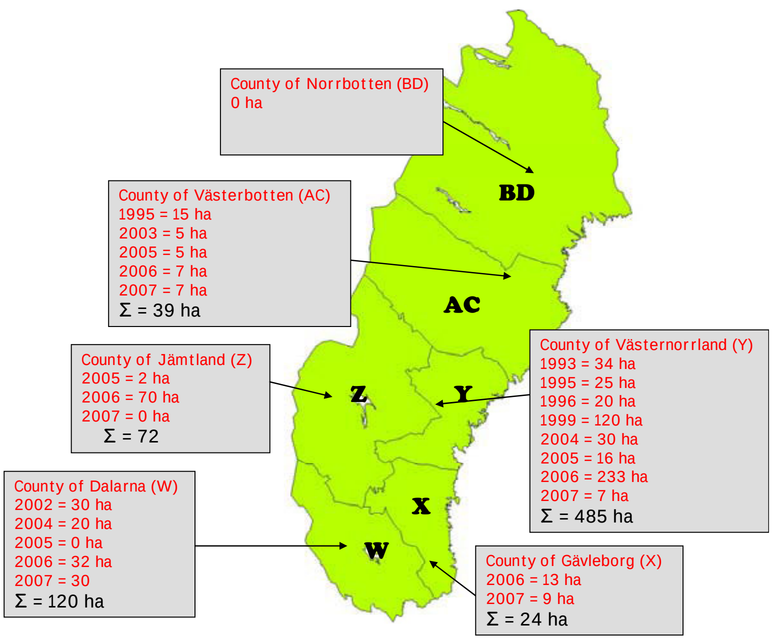

Figure 1. Prescribed fires in protected areas in Northern Sweden.


This is a "Prescribed horror picture", no retention trees and mechanically scarified. Photo: Petter Bohman.

consist of unlogged areas. There are only a few counties that use fire on regular basis in nature reserves. Until now there is only a total of 729 hectares burned in the northern part of Sweden. We must increase the area burned annually if we want to see some major positive changes in biodiversity.

Sweden is currently working with Action Plans for Endangered Species and some of the Actions Plans concern fire-favoured species. The county of Västernorrland has the national responsibility for the action plan for fire-favoured beetles. In that action plan we suggest that a minimum area of 50 hectares per year, and county, should be burned in nature reserves. In the northern counties it gives us a minimum of 300 hectares of high quality burns.

Our objectives are divided in two different levels: main objectives, which are valid for all of our burns, and objectives that are specific for each prescribed fire.

The main objectives are:

– Recreate a fire prone stand structure
– Create options for regeneration of pine and for pine to grow tall
– Increase the amount of dead wood, mainly pine snags (standing dead trees) in a short and longer period of time
– Strengthen the populations of fire-favoured species at landscape level.

Some of the target species are: *Stephanopachys linearis* and *S. substriatus*, *Picoides tridactylus*, *Dryocopus martius*, *Pulsatilla patens*, *Daldina loculata* and *Geranium bohemicum.*

One of the problems is that many nature reserves have a management policy of "free development", which means that man can not do any active management. The nature reserve is left to natural processes. One can wonder what type of natural processes is meant by that. It takes a miracle from a lightning to strike within a 300 hectare large nature reserve. Different species could be waiting for a fire for centuries, because if fire started by lightning occurs outside of the nature reserve it will be suppressed instantly.

The decision to leave an area to "free development" is often done with no regard to fire history or other forms of natural disturbances. That is not reasonable, and we must put a lot of effort to rewrite the plans, so we could use fire in our protected areas. We have already altered some of the management plans and used fire in order to maintain the biological diversity and restore the stand structure shaped by fire. The management method of "free development" is a suitable method for spruce dominated areas. The only process that human can't alter is time. The other natural processes have been changed by man in such a way that we no longer can regard them as disturbance factors. I do believe that we must replace the natural disturbance regimes with human induced ones, such as prescribed fire.

Another problem in Sweden is that it has gone more than 120 years since the latest fire and the forests have become very dense. Very often there are more then 800 trees per hectare, which is too dense if we want a new regeneration of pine. It is also too dense if we want to make it possible for pines to grow as tall as they were before dimension cuttings in the middle of the 19th century. Studies have shown that the pre-industrial forest consisted of approximately 120-200 dominant trees per hectare, and those were very old and huge trees. Often they were more than 300 years old and more than 100 cm in diameter at breast height. In many of our protected areas, old stumps from the dimension logging era, stand as evidence for a forest that no longer exists. Still it is a forest that we might be able to recreate if we are allowed to use the kind of management tools that are required, such as prescribed fire and selective logging when needed. In one of our nature reserve, Stormyran-Lommyran, we started a major restoration in 2002, with a reduction of number of trees per hectare. The surface area of reserve is 1,000 hectares and of that area the forest consists of approximate 600 hectares. The average stand has a mean age of 125 year, 60% pine and 40% spruce. The average stand has 850 stems per hectare, which is too high density. We started to log 50% of the trees, targeting the spruce. A total of 35,000 m^3 of timber was harvested and in some of the logged areas we also removed the "limbs and tops" in order to reduce the fuel load. After selective logging we burned the logged areas. The results have so far been quite good. We have a pre-burning condition of approximate 450 stems per hectare, which allow us to have up to 50% mortality and still have natural stand conditions.

Another important issue is knowledge of fire behavior and biological response to disturbance agents, mainly fire. Therefore we have joined up with three other counties, County of Jämtland (Z), County of Gävleborg (X) and the County of Dalarna (W) (see Fig. 1) and a government agency, Skogsstyrelsen (Swedish Forest Service) to launch an education package in order for becoming forest fire specialists to learn about forest burning. We have seen a lack of skilled and competent people who could conduct a prescribed burn. We have assembled a list of skills and competence required for prescribed burning.

Anyone who wants to use fire must know the physical conditions as well as the technique, otherwise it is easy to fail in one way or another. It is vital that one is involved in both planning and performance of a prescribed fire. One must know WHY and HOW!

After rewriting the management plan, we are able to use prescribed burns to restore our protected areas. Photo: Tomas Rydkvist.

Previously we only had a Burn Boss when we did our burns, independent of the size of the burn. Now we have a Burn Boss, who is in charge of the whole operation, and an Ignition Specialist, who is in charge of the ignition pattern, collecting weather data, reading and taking notes of fire behavior and so on. The Ignition Specialist has a mandate to control all the igniters so we can regulate fire intensity. This type of organization has been beneficial to our burns in the way that we reach our objectives more easily.

We also conducted a test burn in five different plots to evaluate certain products to prevent important features to catch fire. We have to preserve important structures like old pines, snags, high stumps and logs from being burned in a fire. In Sweden there is a shortage of these features in many reserves, so we must find a simple and cost effective way of securing them. We have tested foam, gel and a type of "wet water".

See our website: http//www.y.lst.se/publikationer/rapporter. Look for Publication No: 2007:6 "Test av skum, gel och "wet water" som skydd för substrat vid natuvårdsbränningar. In Swedish with an English summary. We also have a DVD from the burns. If you would like to obtain a copy please contact Tomas Rydkvist.

The first sample plot is burning. Photo: Elin Mattson-Tano.

7 Forest Fires in the Russian Taiga

Heikki Kauhanen

Finnish Forest Research Institute, Kolari Reseach Unit, Muoniontie 21, 95900 Kolari, Finland

7.1 Introduction

A tremendous diversity of climate, soil and vegetation, together with a wide variety of anthropogenic impacts, is inherent in the vast territories of Russia (Shvidenko & Goldammer 2001). The Russian forests stretch through eleven time zones and ten bio-climatic zones and subzones, from tundra in the north to deserts in the south. About 78% of the forests are located in the Asian part and the remaining 22% in the European part of the country. The forested area covers half of the total area of the country and accounts for 23% of the global forest areas (Nilsson & Shvidenko 1997). Almost 95% of the Russian forests belong to the boreal (*taiga* in Russian terminology) vegetation zone. More than 70% of the forested area is dominated by five coniferous tree species (larch, pine, spruce, fir and Siberian pine). The Russian taiga amounts to approximately two-thirds of the global boreal region. It contains about 25% of the global terrestrial biomass, and even a higher percentage of the carbon stored in litter and soils (Conard et al. 2002).

Most people regard fire as a destructive force that should be fought against and quickly extinguished. However, the fact is that wildfire is a natural phenomenon in boreal forest landscapes (Karpachevskiy 2004). In many European countries wildfires are almost completely eradicated as a result of the extremely efficient fire suppression systems. After a long suppression period fire is now tried to reintroduce to forest ecosystems by using controlled burning. The situation in Russia is completely different as its fire suppression system has never been very effective in managed forests, and huge parts of the country remain outside the system of forest fire suppression. This paper presents an overview on forest fires in the Russian taiga.

7.2 Occurrence of fires

7.2.1 Statistics of fires

There are several reasons why fire is a major disturbance factor in Russian forests (Shvidenko & Goldammer 2001). About 95% of the forests are boreal forests, and a major part of them is dominated by coniferous stands of high fire hazard. A significant part of the forested territory is practically unmanaged and unprotected. As a consequence large fires play an important role in this region. Due to slow decomposition of plant material, the forests contain large amounts of accumulated organic matter. A major part of the boreal forest is situated in regions with limited amounts of precipitation and/or frequent occurrences of long drought periods during the fire season.

In the early 20th century, when a fire fighting system was virtually absent, forest fires are believed to have affected between 600,000 and 700,000 hectares per year (Karpachevskiy 2004). The number and distribution of forest fires and area burned vary annually across Russia. High fire frequency and small fire areas are typical of the European part of Russia, whereas the Asian part of the country is characterized by small fire frequency and extensive fire areas. The lower share of the area burned in European Russia is partly due to the differences in the capacity of fire suppression but also to more favourable natural conditions for fire to spread in Asian Russia. According to the official statistics, 20 to 35 thousand wildfires annually affect between 0.5 and 2.5 million hectares of Russian forest (Karpachevskiy 2004). Despite the high number of individual fires, the serious environmental impacts are generally caused by large wildfires (greater than 200 ha) and especially by catastrophic fires. The area of an individual fire scar burned by a catastrophic fire may exceed tens and even hundreds of thousands hectares. On an average, 5% of the large wildfires are responsible for more than 90% of the whole area damaged by fires.

The duration of the fire season is geographically dependent and ranges from 90-100 to 200-250 days per year. There is a clear zonal gradient in the seasonal distribution of fire (Korovin1996). At the southern latitudes fire season is twice as long as in the north. Most fires occur during a four month's period that extends from May through August (Fig. 1). Within the general fire season, there may be two or three distinct peaks of fire activity.

The extent, timing and geographical distribution of fires vary greatly. The annual area burned can vary even ten-fold. About 60 to 90 percent of the area burned annually is usually concentrated in three to six regions. In one or more of these, fires may be of catastrophic character. In Siberia, on an average, about 1 percent of the fires are large (with an area of more than 200 ha) but in dry years this may rise up to 10 percent. However, large fires make up 50 to 80 percent of the burned area (Valendik 1990). In extremely dry years, a similar picture can be observed even in densely populated regions.

7.2.2 Fire cycle

Frequency of fire depends on many natural and anthropogenic factors. Typical fire return intervals in *Pinus sylvestris* forest types in central Siberia have been estimated to range from 25 to 50 years (Furyaev 1996, Swetnam 1996). However, the variation is very large with an upper limit of 250 to 300 years for wet sites and a lower limit of 7 to 15 years or even less for some sites. An interval of only 3 to 4 years have been observed in dry pine and larch forests in densely populated areas. Longer intervals (90-130 years) are more typical for forests dominated by *Larix* species (Furyaev 1996) and by *Abies sibirica* and *Picea obovata*. Fire return intervals decrease from north to south, and are longer on the most well-watered sites along rivers or in areas where forest stands are isolated by wet bogs. From a historical perspective, areas in which no fires have occurred during a single life cycle of a coniferous forest (200-300 years) are negligibly small in the taiga zone (Furyaev 1996).

As a reflection of the difference in dominance and in fire return intervals of the various forest types, about 70 percent of the fires in Russia occur in light coniferous pine and larch-dominated stands (*Pinus sylvestris* or *Larix*), and only about 15 percent in dark (primarily *Abies*, *Picea*) coniferous boreal forest (Korovin 1996). About 80 percent of the area typically burns in surface fires (Furyaev 1996, Korovin 1996), but patchy crown fires are common, and in severe fire seasons, crown fires may dominate.

7.3 Extreme fire seasons in Siberia

Many regions in Russia are known as high wildfire hazard areas. Particularly in Central and Eastern Siberia recurrent extreme fire seasons are common (Ivanova 1996, Valendik 1996, Valendik et al. 2005). In severe fire seasons multiple

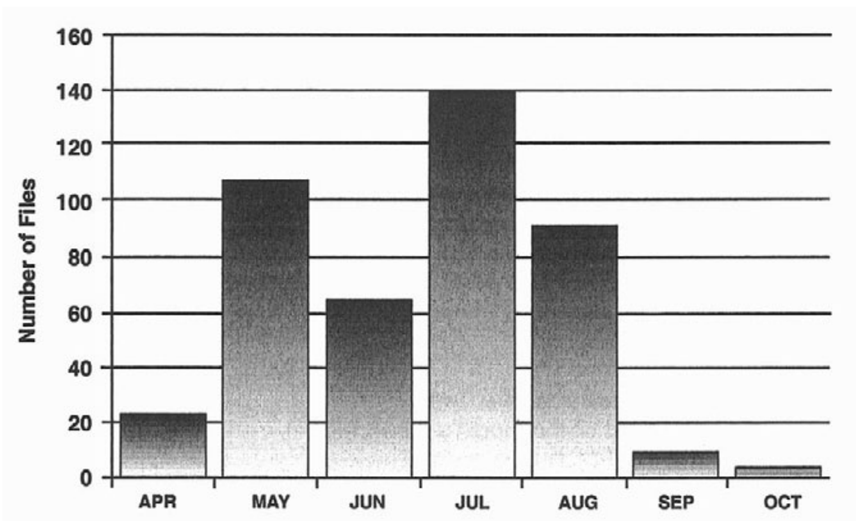

Figure 1. Monthly distribution of fire frequency during the fire season in Russia. (Redrawn from Conard & Davidenko 1998.)

fires may burn over long periods, casting a pall of smoke over large areas (Conard & Ivanova 1997). Large forest fires have been reported in the press as far back as late 19th century. In the early twentieth century, dry years with large forest fires were frequent in Siberia (Valendik 1996).

Shostakovich (1925) reported on extensive fires in Siberia in 1915. The largest fires ever recorded occurred as a consequence of an extended drought in Central and East Siberia. Precipitation in Siberia was about 50-60% of the normal, near the centre of it hardly 30 percent. There were two periods with absolutely no rain in Central Siberia: the first one from mid-June till mid-July, and the second one from the end of July till mid-August. These fires burned for 50 days, and in many places the fires persisted throughout the whole summer. The fires raged in an area covering some 181 million ha, about one-fifth of the area of whole Europe. The main centre of the fires was between Angara River and Nijnya Tunguska, and the total area burned there was estimated at 14.2 milj. ha. In many dried peatlands peat burned over 1.8 m below the surface. The smoke pall from the fires covered 680 million ha, and severely reduced visibility at ground level over a large percent of the area.

Extreme fire seasons are characterized by long rainless periods, high air temperatures and low humidities (Ivanova 1996). The number of precipitation-free days is the major factor controlling the occurrence of large fires (Valendik 1996). In spring, forest stands in many regions attain high flammability very rapidly: 20 rainless days are a critical period. In summer, large fires begin to occur all over the area from southern Siberia throughout Far East after a 30-day drought. These droughts make all vegetation highly flammable, natural fire breaks disappear and fires spread freely (Ivanova 1996, Ivanova & Ivanov 2005).

Analysis of weather information and fire periodicity has revealed that e.g. in Central Yakutia some 50 extreme fire seasons occurred from 1670 through 1992 (Ivanova 1996). They repeated once a decade and covered 2-3, sometimes even 4 consecutive years. E.g. in 1948, long and severe drought prevailed across Yakutia over the three summer months. During that period, 550 fires burned, 125 of which were large fires. Several extreme fire years (1987, 1992, 1998, 2002, 2003) have occurred during the last two decades. In 2002, a large number of wildland fires occurred near Yakutsk. The fires started from early May and continued into September, with a burnt area estimated at more than 2.3 million ha (Hayasaka 2003). In 2003, fires burned a total of 14.5 million hectares (Mollicone et al. 2006). Large climate anomalies occurred during this period that increased the likelihood of fire ignition and propagation. In the same year the Avialesookhrana (Aerial Forest Fire Service of Russia) continued to be faced with insufficient budgets for operations (Goldammer et al. 2003). With the reduced budgets it was not possible to suppress wildfires in an early stage. Consequently the wildfires grew large in size and became uncontrollable in most cases.

All across Siberia and Far East, large fires vary widely in both frequency and time of occurrence. In Western Siberia, fires are relatively infrequent, except Tomsk region, where they have increased in number during recent years. In most parts of Eastern Siberia and Far East, fires are an annual event, and large-scale fire outbreaks are reported once every 3 to 4 years, often occurring in two consecutive years (Valendik 1996). In the huge territories of Siberia it is impossible to fight fires in all forest zones. Economy of the country will not stand to such kind of expenses. Moreover, full exclusion of wildfires in boreal forests leads to extra fuel loads (Valendik et al. 2005).

7.4 Human and forest fires

7.4.1 Human influence on fire regime

Humans have historically had a significant impact on the natural fire regime, as fire has been used in maintaining grasslands, and in the practice of slash and burn agriculture (Karpachevskiy 2004). Furthermore, fire has often followed industrial practices, such as logging, mining and charcoal production. Forest fires became more frequent in the 1930s and 1940s and especially in the 1950s and 1960s, as Soviet authorities sent thousands of people into the sparsely populated taiga to survey and exploit the precious natural resources. Thousands of kilometres of ground and railroads penetrated to the taiga, making it more accessible for people and, since that time, tens of millions of hectares of pristine taiga in European Russia, Siberia and the Russian Far East have been destroyed by fire.

The exact proportion of anthropogenic fires is unknown, since the official statistics contain a "fires of undetermined cause" category (Karpachevskiy 2004). The average proportion of anthropogenic fires is estimated to be 80-90 percent for Russia as a whole. The importance of lightning as an ignition source varies greatly geographically, with the highest percent of lightning ignitions in relatively unpopulated areas with a pronounced continental climate such as the Krasnoyarsk and Yakutia regions (Conard & Davidenko 1998). A proportion of 33-67% for the spontaneous fires has been estimated in Evenkia and Yakutia in northern Siberia, depending on the time period (Ivanov 1985). Nonetheless, even in these regions, a large percentage of fires are human-caused.

Karpachevskiy (2004) states that the proportion of natural fires is likely overestimated. In opposite to that Conard and Davidenko (1998) suggest that, according to newer information, the importance of lightning ignitions may have been underestimated. Currently, the majority of Russia's anthropogenic fires are caused by agricultural burns, the careless behaviour of children, local hunters, fishermen and berry/mushroom collectors, and sparks from vehicles. Most of these fires take place in close proximity to settlements, roads, agricultural fields and other forms of human infrastructure. The large influence of human populations on fire occurrence is well-illustrated by Korovin (1996), who shows that about 68 percent of fires occur within 5 km of a road, and 60 percent of fires occur within 10 km of a populated area.

7.4.2 Fire suppression

The major force in the fire detection and fighting is Avialesookhrana (AO) with 24 regional airbases across Russian Federation. The use of aircraft began as early as in 1930s and, the application of remote sensing data began in 1970s. During the last few decades, about 80-85 percent of all fires have been detected by aviation and about 50 percent of all fires detected are extinguished during the first day. Fires that are not extinguished during the first day often become very large and difficult to extinguish. Since 1990s the system of fire detection and fighting has been negatively impacted by financial and logistical constraints.

In Russia, the boreal wildfire problem is both severe and poorly documented. Fire detection and fighting across the vast taiga is a great challenge. The Russian government only actively suppresses fires in less than two-thirds (62-65%) of its boreal region, typically leaving the rest to burn (Kasischke et al. 1999). Quite often, firefighters are not even aware of wildfires in remote regions until after they have been burning for days.

7.5 Use of remote sensing

Since it is not economically feasible to fight all fires, many of them are allowed to burn themselves out. Regarding to the size of Russian taiga and the remoteness of the unprotected territory satellite remote sensors are the only cost effective way of monitoring fires in the boreal regions.

Scientists who monitor fires on a global scale suspect that the Russians greatly underestimate the total area burned on an annual basis. There are some satellite data estimating the total extent of fires for all or major parts of Russia. Based upon analysis of AVHRR (Advanced Very High Resolution Radiometer) data, fire scientists estimate that roughly 12 million hectares (120,000 square km) of Eurasian boreal forest burned in 1987, and most of that was in areas actively monitored by Russian foresters (Kasischke et al. 1999). This figure compares dramatically with the estimate of 1.27 million hectares burned reported by Russian officials. Cahoon et al. (1994), based also on AVHRR data, determined the area burned in the Russian Far East and eastern Siberia in 1987 to be 14.4 million ha.

Extensive independent research on Russian forest fires has been conducted by the Global Fire Monitoring Center, based in Freiburg, Germany. This research showed that the 1.834 million ha of burnt land that AO reported in for the severe fire year 2002 for their jurisdictional area may not be an accurate reflection of the complete picture (Goldammer et al. 2003). These findings were further supported by the Krasnoyarsk Fire Laboratory (Sukachev Forest Institute), which found that 11.7 million ha burnt during the same period in Asian Russia alone (Sukhinin 2003, see also Fig. 2). Additional researchers have also found major discrepancies with other AO data. For example, the Global Burnt Area 2000 initiative (GBA-2000), which has produced a global dataset on burnt vegetated areas for the year 2000, found that 3.11 million ha forest and 3.31 million ha woodland burnt in Russia, compared to the 1.64 million ha that was reported by AO. For 1998, the satellite data showed that 13.3 million ha burnt in Siberia, five times higher than the area reported by AO.

7.6 Carbon cycle and Russian forest fires

Boreal forests play a unique role in the global carbon cycle and climate system (Bonan et al. 1995), as they constitute a significant part of the world's forest area and organic carbon storage. It has been estimated that the vegetation, soils, and permafrost layer of the boreal zone represent around 37% of the total terrestrial carbon pool, and, therefore the region is extremely important with regard to the Earth's carbon cycle (Goldammer & Furyaev 1996).

The Russian forests are of great interest to scientists studying the interaction of human and natural disturbances, especially those interactions affecting the terrestrial component of the global carbon cycle. It has been estimated that the closed forests of Russia contain some 41 billion tons of vegetative carbon, and in addition to that, the top layer (one meter) of soil of forest ecosystems contains about 130 billion tons of carbon (Shvidenko et al. 2000).

Global climate models linking area burned with fire-season temperature predict that global warming will bring significant increases in fire regimes. E.g. results of Stocks et al. (1998) indicated an earlier start to the fire season, an earlier start in high to extreme fire severity, a later end in the fire season, and a dramatic increase in the area under high to extreme fire danger. Notably, the area under extreme fire danger in Siberia during the summer months was projected to be three times the area affected in Canada.

Nowhere on Earth is global warming faster than in the Arctic region. In northern Siberia, average temperatures have risen 1 to 3°C over the past 30 years, whereas the worldwide average increase in that time is 0.6°C (Ranson et al. 2007). Projected increases in the severity of the continental climate in Russia suggest longer fire seasons and much higher levels of fire danger. The inevitable result will be an increase in the number, size, and severity of boreal fires, with huge impacts on the global carbon cycle and the Russian economy.

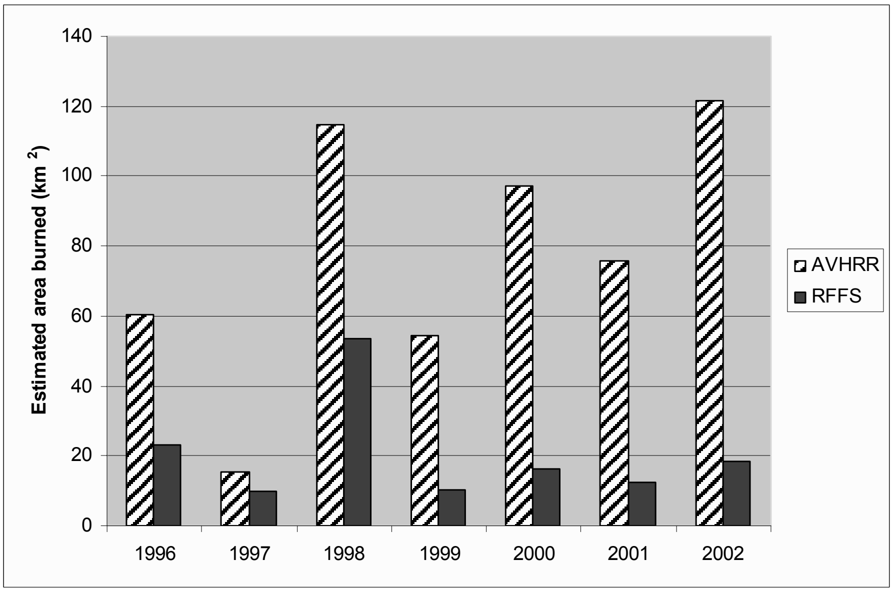

Figure 2. Estimated annual area burned for the period of 1996 to 2002 from AVHRR data vs. reported by Russian Federal Forest Service (RFFS). Data from Sukhinin et al. 2004.

7.7 Conclusions

Fire is the major annual disturbance throughout the Russian forest, especially in large portions of the more remote areas, where fire suppression is less intensive or impossible (Bergen et al. 2003). This disturbance exceeds the annual area harvested or disturbed by other natural agents, such as insects. Although some fires are a natural component of the boreal ecosystem, most of the fires in the Russian taiga are caused by human activities. With the vast quantities of carbon reserves, Russian forests play a critical role in the global climate system and global carbon cycling (Goldammer 2003). Any changes in their carbon balance have potential to affect global atmospheric CO^2.

References

Bergen, K., Conard, S. G., Houghton, R. A., Kasischke, E. S., Kharuk, S., Krankina, O., Ranson, J., Shugart, H. H., Sukhinin, A. & Treyfeld, R. F. 2003: NASA and Russian scientists observe land-cover/land-use change and carbon in Russian forests. – Journal of Forestry 101: 34-41.

Bonan, G. B., Chapin III, F. S. & Thompson, S. L. 1995: Boreal forest and tundra ecosystems as components of the climate system. – Climate Change 29: 145–167.

Cahoon, D. R., Stocks, B. J., Levine, J. S., Cofer, W. R., Pierson, J. M. 1994: Satellite analysis of the severe 1987 fires in northern China and southeastern Siberia. – Journal of Geophysical Research. 99: 18627-18638.

Conard, S. G & Davidenko, E. P. 1998: Fire in Siberian Boreal Forests. Implications for Global Climate and Air Quality. – USDA Forest Service, General Technical Report PSW-GTR-166: 87-94.

— & Ivanova, G. A. 1997: Wildfire in Russian boreal forests – potential impacts of fire regime characteristics on emissions and global carbon balance estimates. – Environmental Pollution 98: 305-313.

— , Sukhinin, A. I., Stocks, B. J., Cahoon, D. R., Davidenko, E. P. & Ivanova, G. A. 2002: Determining effects of area burned and fire severity on carbon cycling and emissions in Siberia. – Climatic Change 55: 197-211.

Furyaev, V. V. 1996: Pyrological regimes and dynamics of the southern taiga forests in Siberia. – In: Goldammer, J. G. & Furyaev, V. V. (eds.), Fire in ecosystems of boreal Eurasia. Kluwer, Dordrecht. Pp. 168-185.

Goldammer, J. G. 2003: Fire ecology of the recent Anthropocene. – Keynote lecture at the 2nd International Wildland Fire Ecology and Fire Management Congress, Orlando Florida, USA, November 16-20. – <http://ams.confex.com/ams/pdfpapers/68542.pdf>, cited November 28, 2008.

— & Furyaev, V. V. 1996: Fire in ecosystems of boreal Eurasia: Ecological impacts and links to the global system. – In: Goldammer, J. G. & Furyaev, V. V. (eds.), Fire in ecosystems of boreal Eurasia. Kluwer, Dordrecht. Pp. 1-20.

— , Sukhinin, A. & Csiszar, I. G. 2003: The current fire situation in the Russian Federation: Implications for enhancing international and regional cooperation in the UN Framework and the Global Programs on Fire Monitoring and Assessment. – International Forest Fire News 29: 89-111.

Hayasaka, H. 2003: Forest fires and climate in Alaska and Sakha: Forest fires near Yakutsk. – Extended abstract, 5th Symposium on Fire and Forest Meteorology, 2nd International Wildland Fire Ecology and Fire Management Congress. – <http://ams.confex.com/ams/FIRE2003/techprogram/paper_66025.htm>, cited November 28, 2008.

Ivanov V. A. 1985: Lesnye pozhary i ikh posledstviya. [In Russian: Forest fires and their consequences]. Krasnoyarsk. Pp. 38-46.

Ivanova, G. A. 1996: The extreme fire season in the central taiga forests of Yakutia. – In: Goldammer, J. G. & Furyaev, V. V. (eds), Fire in ecosystems of boreal Eurasia. Kluwer, Dordrecht. Pp. 260-270.

— & Ivanov, V. A. 2005: Fire regimes in Siberian forests. – International Forest Fire News 32: 67-69.

Karpachevskiy, M. 2004: Forest fires in the Russian Taiga: Natural disaster or poor management? – Taiga Rescue Network Factsheet, Jokkmokk, Sweden. 8 p.

Kasischke, E. S., Bergen, K., Fennimore, R., Sotelo, F., Stephens, G., Janetos, A. & Shugart, H. H. 1999: Satellite imagery gives clear picture of Russia's boreal forest fires. – Eos Transactions 80: 141-147.

Korovin, G. N. 1996: Analysis of the distribution of forest fires in Russia. – In: Goldammer, J. G. & Furyaev, V. V. (eds), Fire in ecosystems of boreal Eurasia. Kluwer, Dordrecht. Pp. 112-128.

Mollicone, D., Eva, H. D. & Achard, F. 2006: Human role in Russian wild fires. – Nature 440: 436-437.

Nilsson, S. & Shvidenko, A. 1997: The Russian forest sector. – A position paper for the World Commission. – <http://www.iisd.org/wcfsd/russianforestsector.pdf>, cited November 28, 2008.

Ranson, J., Kharuk, S. & Howl, J. 2007: Expedition to Siberia. – <http://earthobservatory.nasa.gov/Study/SiberiaBlog/>, cited November 28, 2008.

Shostakovitch, V. B. 1925: Forest conflagrations in Siberia. – Journal of Forestry 23: 365-371.

Shvidenko, A. & Goldammer, J. G. 2001: Fire situation in Russia. – International Forest Fire News 24: 41-59.

Shvidenko, A. Z., Nilsson, S., Stolbovoi, V. S., Gluck, M., Schepazhenko, D. G. & Rozhkov, V. A. 2000: Aggregated estimates of the basic parameters of biological production and the carbon budget of Russian terrestrial ecosystems: 1. Stocks of plant organic mass. – Russian Journal of Ecology 31: 371-378.

Stocks, B. J., Fosberg, M. A., Lynham, T. J., Mearns, L., Wotton, B. M., Yang, Q., Jin, J. Z., Lawrence, K., Hartley, G. R., Mason, J. A. & McKenney, D. W. 1998: Climate change and forest fire potential in Russian and Canadian boreal forests. – Climatic Change 38: 1–13.

Sukhinin, A. I. 2003: The 2002 fire season in the Asian part of the Russian Federation: A view from space. – International Forest Fire News 28: 18-28.

— , French, N. H. F., Kasischke, E. S., Hewson, J. H., Soja, A. J., Csiszar, I. A., Hyer, E. J., Loboda, T., Conrad, S. G., Romasko, V. I., Pavlichenko, E. A., Miskiv, S. I. & Slinkina, O. A. 2004: AVHRR-based mapping of fires in Russia: New products for fire management and carbon cycle studies. – Remote Sensing of Environment 93: 546-564.

Swetnam, T. W. 1996: Fire and climate history in the central Yenisey region, Siberia. – In: Goldammer, J. G. & Furyaev, V. V.(eds), Fire in ecosystems of boreal Eurasia. Kluwer, Dordrecht. Pp. 112-128.

Valendik, E. N. 1990: Fighting with big forest fires. [In Russian]. – Nauka, Novosibirsk, Russia. 193 p.

— 1996: Temporal and spatial distribution of forest fires in Siberia. – In: Goldammer, J. G. & Furyaev, V. V. (eds), Fire in ecosystems of boreal Eurasia. Kluwer, Dordrecht. Pp. 129-138.

— , Vekshin, V. N. & Lako, R. 2005: Basics of fire management in Eurasia. – International Forest Fire News 32: 62-63.

8 Forest Fires in Norway

Målfrid Toeneiet

Norwegian Forest and Landscape Institute, Pb 115, 1431 Ås, Norway

Research on natural fire regimes has not come as far in Norway as the rest of Fennoscandia. Currently we are working with reconstructing historical fire regimes and intervals in Trillemarka in south-central Norway. Because of limited knowledge about historical fire regimes, there has been no use of fire as a management tool in Norway. The closest we have come to a prescribed burning is a small scientific burning of a 12 ha large forested area in Hedmark county in 2002 (Gongalsky et al. 2006). There was also a couple of scientific burnings in the 1990s when the certification standards called "Levende Skog" were prepared. Prescribed burning of clear cuttings was relatively common in the mid 1950s with close to 1,500 hectares yearly burned area (Skoklefald 1973), but use of fire for rejuvenating clear cuttings is not in use anymore.

Norway is a country with large climatic and topographic variation. The Scandinavian mountain range divides the country in a south-north direction, and fjords are cutting in to the mountain range from west. The costal areas are among the areas with most precipitation in the world, whereas the south-eastern parts towards Sweden have a more continental climate. The immigration history of tree species differs throughout the country. This makes Norway an interesting object for studying how different forest types, climate and other factors affect the forest fires spatial extent and frequency (Bleken et al. 1997).

8.1 Forest fires in Norway for the last 100 years

Registration of fire statistics became a governmental responsibility in 1913. The statistics are relatively precise regarding the number of forest fires, whereas the registration of fire size is assumed to be more rough estimates (Øyen 1998).

The years with the largest area burned in Norway in the registration period (1913-2006) are 1937, 1942, 1947, 1950, 1959, 1964, 1972, 1974 and 2006, with total areas of more than 3,500 hectares. The largest fire-years in productive forests are 1959, 1976, 1992 and 2006 with more than 1,500 hectares burned (Fig. 1). Average yearly burned area in the 94 year period is 1,256 hectares land and 315 hectares of productive forest.

7.4 mill hectares of Norway is covered with productive forest. An average of 315 hectares burned productive forest each year corresponds to 0.04‰. A continuation of this fire regime will theoretically give a fire return interval of 23,500 years.

The number of fires has varied over the years, and there is a marked peak in number of fires from 1960 to 1980 (Fig. 2). The mean fire size is showing a declining trend through the period from 1913 to 2006 (Fig. 3). This is probably due to increased number of vacation properties and

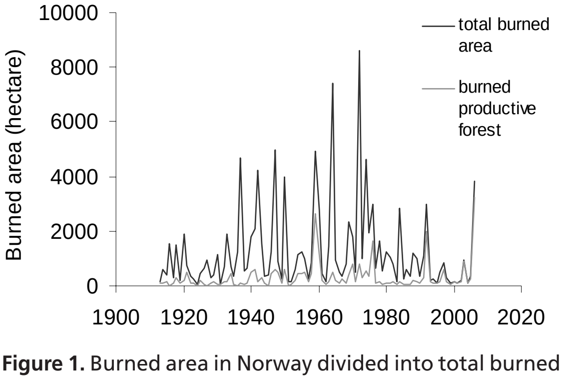

Figure 1. Burned area in Norway divided into total burned area, and burned productive forest. Source: Directorate for Fire and Explosion Prevention.

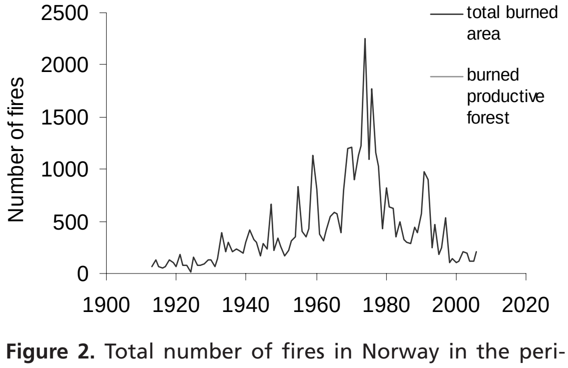

Figure 2. Total number of fires in Norway in the period 1913-2006. Source: Directorate for Fire and Explosion Prevention.

technical installations like power lines, which starts more fires. In the same period fire suppression has become more effective (Øyen 1998). Year 2006 stands out from the general trend with a high proportion of burned productive forest and large mean fire size.

Of the total number of fires during the last 10 years (1997-2006), lightning fires accounted for 14%. The proportion of fires which the cause could not be determined was 34% (Fig. 4).

South-eastern parts of Norway have the highest density of lightning strikes. These areas also have the highest amount of lightning ignitions with an average of 27.2 lightning ignited burns each year. This corresponds to a lightning ignition density of 0.08/10,000 ha/yr (Øyen 1998), which is lower than what has been found in south- eastern Sweden (0.23/10,000 ha/yr), but comparable to northern Sweden with a density of 0.05/10,000 ha/yr (Granström 1993).

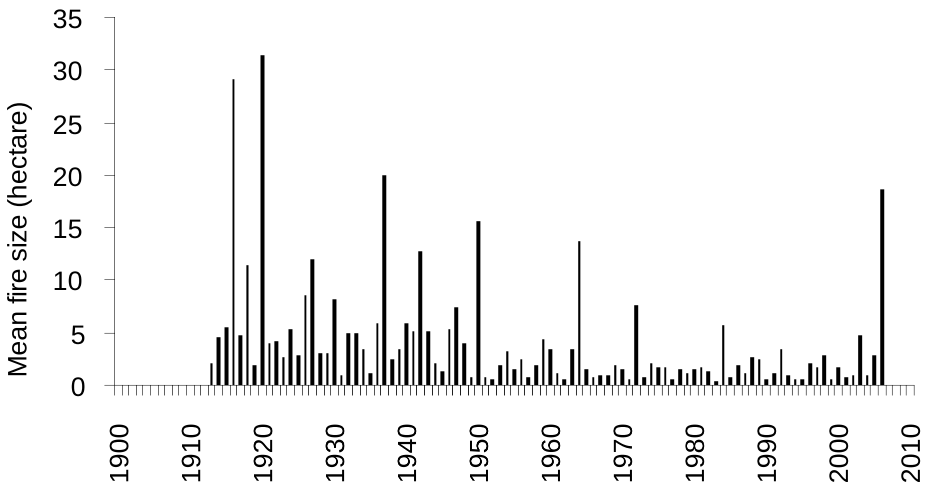

Figure 3. Mean fire size of total area burned. Source: Directorate for Fire and Explosion Prevention.

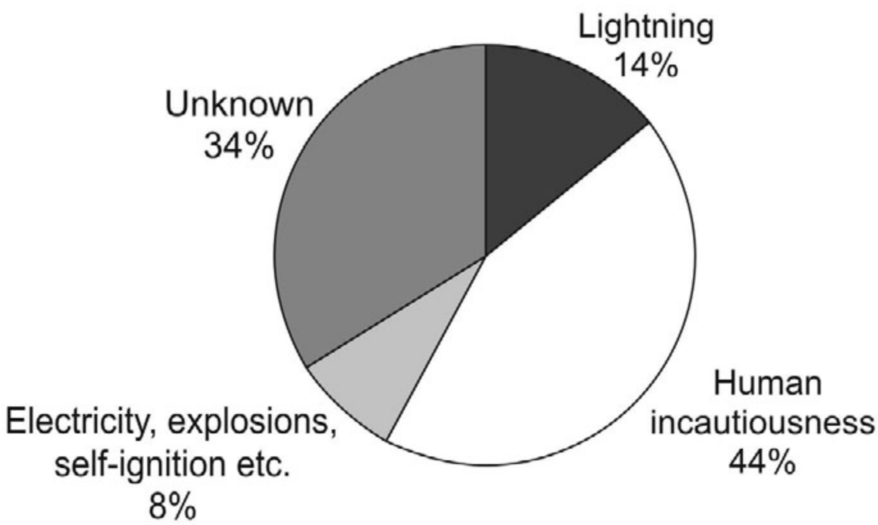

Figure 4. Cause of fire of total area burned. Source: Directorate for Fire and Explosion Prevention.

8.2 Fire history in south-central Norway for the last 600 years

There are a few Norwegian studies on the long-term (i.e. Holocene) variation in fire activity (Tryterud 2003, Molinari et al. 2005, Ohlson et al. 2006), but there is only one dendrochronological study on fire history (Groven & Niklasson 2005).

In a newly started study in south-central Norway we have dated 330 cross-sectioned samples with 640 fire scars. The first confirmed fire year was in 1413, and the last was in 1821 (Toeneiet et al. 2007). The study is a complete sampling of all fire-scarred material (living trees, stumps, snags and logs) in a 3.4 km^2 nature reserve in Trillemarka, south-central Norway.

Preliminary results show low fire frequency in the period 1400-1550 (1 fire per 30 years), and high fire frequency in the period 1550 to 1700 (1 fire per 9 years). 1700-1850 had 1 fire per 21 years, and after 1850 there is no confirmed fire in the area. This corresponds well to historical facts. 1400-1550 was a period with low population density due to the Black Death epidemic (1349-1350), and few fires are probably due to low anthropogenic influence. 1550-1700 was a period with population increase and relatively low timber value. High fire frequency can be explained by human igniting fires to improve pasture conditions. By the end of the 17th century several new laws prohibited use of fire, and at the same time the timber value increased. Fewer fires in the period 1700-1850 and absence of fire during the last 150 years indicate less active anthropogenic use of fire, and more effective fire suppression.

All sampled trees are plotted on a GPS, making it easy to reconstruct the size and shape of each fire. The general trend is that fires in the 15th and 16th century were larger than those in the 17th century (Fig. 5).

8.3 Conclusion

Today forest fire is practically absent from Norwegian forest ecosystems. Reconstruction of historical fire regimes is, however, implying that fire has been a natural part of Norwegian forest ecosystems. Only fragments of Norwegian fire history are documented, and the topographical and climatic variance makes it important to document more of the history over larger areas. Use of prescribed burning will probably be an important tool in future forest management.

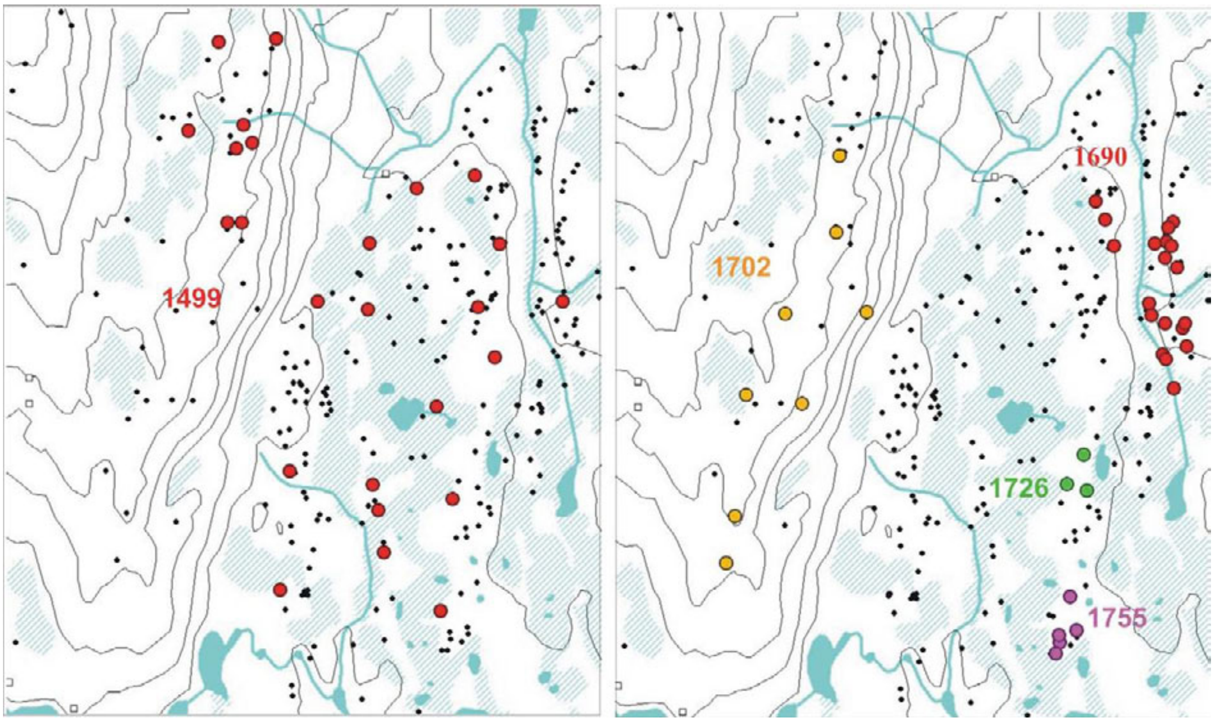

Figure 5. The map (1.7 x 2.0 km) to the left shows the size of the 1499 fire (red dots), while the map to the right shows the fire sizes in 1690 (red), 1702 (orange), 1726 (green), and 1755 (purple). The small black dots show the collected samples from the study area in Trillemarka, south-central Norway.

References

Bleken, E., Mysterud, I. & Mysterud, I. (eds) 1997: Forest fire and environmental management: A technical report on forest fire as ecological factor. – Contracted report, Directorate for Fire and Explosion Prevention and Department of Biology, University of Oslo. 266 pp.

Gongalsky, K. B., Midtgaard, F. & Overgaard, H. J. 2006: Effects of prescribed forest burning on carabid beetles (Coleoptera: Carabidae): a case study in south-eastern Norway. – Entomologica Fennica 17: 325-333.

Granström, A. 1993: Spatial and temporal variation in lightning ignitions in Sweden. – Journal of Vegetation Science 4: 737-744.

Groven, R. & Niklasson, M. 2005: Anthropogenic impact on past and present fire regimes in a boreal forest landscape of south-eastern Norway. – Canadian Journal of Forest Research 35: 2719-2726.

Molinari, C., Bradshaw, R. H. W., Risbøl, O., Lie, M. & Ohlson, M. 2005: Long-term vegetational history of a Picea abies stand in south-eastern Norway: Implications for the conservation of biological values. – Biological Conservation 126: 155-165.

Ohlson, M., Korbøl, A. & Økland, R. H. 2006: The macroscopic charcoal record in boreal forested peatlands in South-east Norway. – The Holocene 16: 731-741.

Skoklefald, S. 1973: Virkning av skogbrann og/eller flatebrenning på vegetasjonsutviklingen. En kort oversikt basert på viktigere nordisk litteratur. [In Norwegian]. – NISK. 12 pp.

Toeneiet, M., Rolstad, J. & Storaunet, K. O. 2007: 600 års brannhistorikk i Trillemarka. [In Norwegian]. – Norsk Skogbruk 3/07: 20-22.

Tryterud, E. 2003: Forest fire in Norway: from fire-disturbed pine forests to fire-free spruce forests. – Ecography 26: 161-170.

Øyen, B. H. 1998: Skogbrann i Norge de siste 200 år. [In Norwegian]. – Oppdragsrapport, Norsk institutt for skogforskning 8/98. 30 pp.

9 Research and Forest Fires

Pasi Puttonen

Finnish Forest Research Institute, Unioninkatu 40A, 00170 Helsinki, Finland

Fires in forests support many ecosystems' services. Forest fires are an integral part of the forest succession by controlling composition and structure of forests and their growth and dynamics. Boreal forest ecosystems and tree species are adapted to the periodic passage of fire, and some ecosystems might disappear in the absence of fire. Fires maintain the vegetation mosaic in the landscape. The mosaic, in turn, constitutes the underlying basis for plant and animal biodiversity within the ecosystem.

Fire behaviour, fire severity, and fire regime influence on the response of forest ecosystems to fire. Understanding fire behaviour and fire regime is necessary for interpreting fire effects. Fire regime includes such factors as fire intensity, fire interval, fire season, and size of the fire. Many effects of fire are at the ecosystem level and have influence on physical environments and landscapes. These include fire impacts on nutrient and chemical cycling, erosion, hydrology, landscape level patterns and global carbon cycling. Forest fires rearrange energy and mass flows in a forested area, and a plant and animal succession starts with species adapted for those new conditions.

There is no one straightforward answer to where, when and how to apply prescribed fire. Past fire regimes provide some guidelines but use of fire is also an ethical question; what type of forest structures and futures we want to create. In today's silviculture, prescribed burns should create conditions to support specific values, at specific places in a specified future forest.

There is a substantial lack of investigations on economic – including environmental economic – success of prescribed burning / restoration burning for ecosystem management objectives. A challenge is in the need to define production functions to identify short-, mid- and long-term relationships between prescribed burning and ecological effects.

Research question under boreal condition include further information needs on fire behaviour for e.g. forest fire danger assessment, models of forest fire spread and extreme fire behaviour. Fire economics and policy economic would be needed to study and develop impact models of fire risk and vulnerability assessment and emergency response systems.

Forest ecology research provides a basis for management and further on fire ecology and how it affects stand structure and function, study environmental impacts, especially cumulative effects in the ecosystems as well as forest material characterization. Monitoring systems, along with supporting research, will be needed as cumulative effects of our current practices not known – long-term goals cannot be achieved without monitoring and modification through time. In forest restoration, the basic question how to achieve desired ecosystem conditions will sustain.

10 Monitoring of Forest Restoration in the Green Belt LIFE Project – First Results from Prescribed Fire Treatments

Anne Tolvanen, Anne-Maarit Hekkala, Marja-Leena Päätalo & Oili Tarvainen

Finnish Forest Research Institute, Muhos Research Unit, Kirkkosaarentie 7, 91500 Muhos, Finland

10.1 Background

Green Belt is an extensive network of old-growth forests, aapa mires, boreal hills and arctic fells along the border between Finland, Russia and Norway. In order to improve the conservation status of protected areas along the Green Belt, Metsähallitus has carried out restoration of forests and peatlands in 13 Natura 2000 areas in Koillismaa and Kainuu as a part of the Green Belt Life project. The project operates from 2004 to 2008. The Finnish Forest Research Institute (Metla) acts as a partner and is responsible for the planning of restoration and the monitoring of forests. The purpose of the forest monitoring is to compare how different restoration methods work to re-establish the attributes and functioning of forests towards those of natural forests, and to detect how different forest-dwelling species respond to the restoration. Monitoring of peatlands and reforested forest roads is being carried out with supplementary funding from Metla. Due to the experimental setup of restoration and consistent monitoring of the restored forests, peatlands and forest roads in several Natura 2000 areas, Metla's research forms the most extensive scientific restoration study in Finland.

The vision of the Green Belt Life project lies in the recent ecological knowledge showing that restoration of forests located close to existing source areas of target species is most efficient (e.g. Hanski 2000). Restoration near high-quality forest stands facilitates the migration of the species and minimizes the time delay of the colonization. For example in southern Finland, most protected areas are small and have been recently managed (see Horne et al. 2006 and references therein). Restoration will not necessarily facilitate the colonization of threatened species, if there are no nearby source populations from where the migration can occur. The project area of Green Belt Life lies in the immediate vicinity of old-growth forests of Russia, which can act as a source area of for example saproxylic and fire-dependent insects and decomposing fungi. The project area is also believed to be sufficiently large to serve as a source area to smaller and fragmented areas after restoration. Since most protected areas within Green Belt Life are in a reasonably natural state, restoration improves the already good conservation status of the region rather than tries to introduce landscapes, which have already disappeared from the area.

A significant part of forests are being restored using prescribed fires in the Green Belt Life project. Fire is considered an important source of heterogeneity in boreal forests. For example fire-adapted and saproxylic beetles have declined dramatically throughout the northern Europe due to efficient forest management practices and fire suppression (Zackrisson 1977, Wikars 2002, Hanski 2000, Rassi et al. 2001). Restoration of forests using prescribed fire aims at creating post-fire habitat mosaics resembling those found in naturally fire-dynamic landscapes (Kuuluvainen et al. 2002).

In this proceeding, we present the forest monitoring setup of the Green Belt Life project. We also give first results on the impacts of prescribed fire on the burn level of lying trees and on saproxylic beetle assemblages in two Natura 2000 sites, Pahamaailma and Elimyssalo. The latest inventories in Green Belt Life were finished in autumn 2007. Hence the results presented here comprise a preliminary part of what is forthcoming from the Green Belt Life project.

10.2 Methods

Forest monitorings were established at four Natura 2000 areas; Oulanka, Pahamaailma, Elimyssalo, and Lentua, prior to restoration in 2005. These areas were chosen for monitoring, as it was either possible to compare the impacts of contrasting restoration methods on the forests (Pahamaailma, Elimyssalo, Lentua), or because other factors, such as the impact of reindeer grazing (Oulanka) could be investigated. Restoration methods varied slightly from site to site (Table 1). In Pahamaailma and Elimyssalo, four restoration methods were applied along with untreated controls (Table 1). In this proceeding, we only discuss two burning treatments in Pahamaailma and Elimyssalo, in which the amount of burn load was being compared. Forests in Pahamaailma are over 120 years old, while those in Elimyssalo are 20-50 years old.

In each Natura 2000 area, four replicates of each restoration method were applied on at least 75 m x 100 m study plots. The study plots were split into three 150 m^2 circles, in which variables related to the development of forest structure and biodiversity are being monitored (Fig. 1). Pre-restoration inventories were completed in 2005, restoration was carried out in 2006, and the post-restoration inventories were done in 2006 and 2007.

All standing and lying trees were mapped within the 150 m^2 circles and recorded for their species, size, and the average levels of decay and burn. We report here the timber volume of lying trees, being classified into four burn levels: 1) mostly unburnt, 2) bark slightly burned, 3) bark burned but phloem alive, 4) charred wood.

Saproxylic beetles were monitored in control and two burn load treatments in Pahamaailma and Elimyssalo. Beetles were collected with six

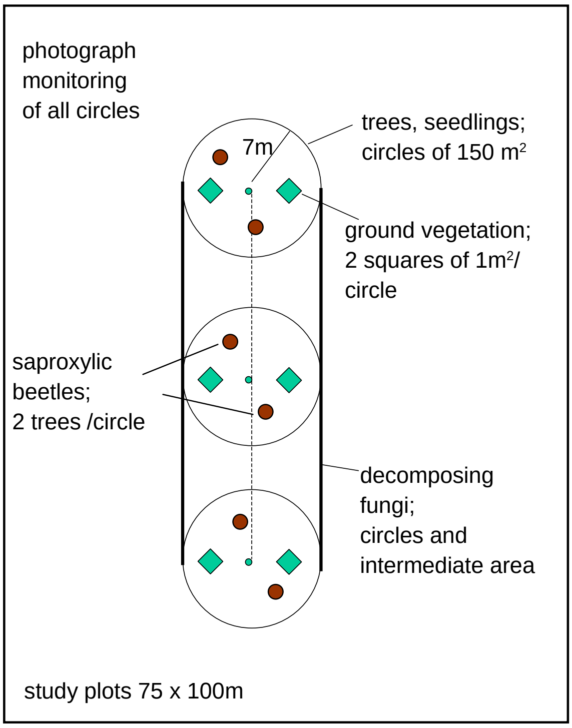

Figure 1. Monitoring setup in the forests.

Table 1. Restoration methods under investigation in different Natura 2000 areas. All areas had also untreated controls.

Oulanka	Pahamaailma	Elimyssalo	Lentua
Burning with low burn load (10-30 m^3/ha)	Burning with low burn load (10-30 m^3/ha)	Burning with low burn load (10-30 m^3/ha)	
	Burning with moderate burn load (40-50 m^3/ha)	Burning with moderate burn load (40-50 m^3/ha)	
	Adding of decayed wood by 10-30 m^3/ha	Adding of decayed wood by 10-30 m^3/ha	Adding of decayed wood by 10-30 m^3/ha
	Adding of decayed wood by 40-50 m^3/ha	Adding of decayed wood by 40-50 m^3/ha	
			Adding of decayed wood by 10-30 m^3/ha using storm simulation
Reindeer fencing of burnt and unburnt sites			

window traps at each study site from mid-May to mid-September in 2005, 2006 and 2007. Species were identified in the laboratory; the emphasis was on saproxylic species. Difficult staphylinids and *Atomarias* were not identified. So far, only beetles from 2005 and 2006 have been identified.

10.3 Results and discussion

Burn load treatment had no impact on the burn level of lying trees in Pahamaailma, whereas in Elimyssalo the percentage of higher burn levels was slightly greater in burn load 40 m^3/ha compared with burn load 20 m^3/ha (Fig. 2). Most lying trees were of burn level 2, indicating a relatively low burning intensity. It appeared that only old lying trees, which had been dead and decayed already before restoration, produced charred wood of burn level 4.

Altogether 27,427 beetle individuals were collected during the pre- and post-treatment years and identified into 390 species. The species richness of saproxylic species increased significantly at all burned sites after fire, whereas the species richness remained unchanged at the control sites (Fig. 3a). The increase in the burn load had a slight positive effect on saproxylic species richness in both study areas. Also the number of saproxylic beetle individuals increased significantly at the burned study sites (Fig. 3b).

The number of red-listed species (including NT, VU, EN) increased significantly at the burned sites both in Pahamaailma and Elimyssalo (Fig. 4). Altogether, 13 red-listed species were caught from the burned sites.

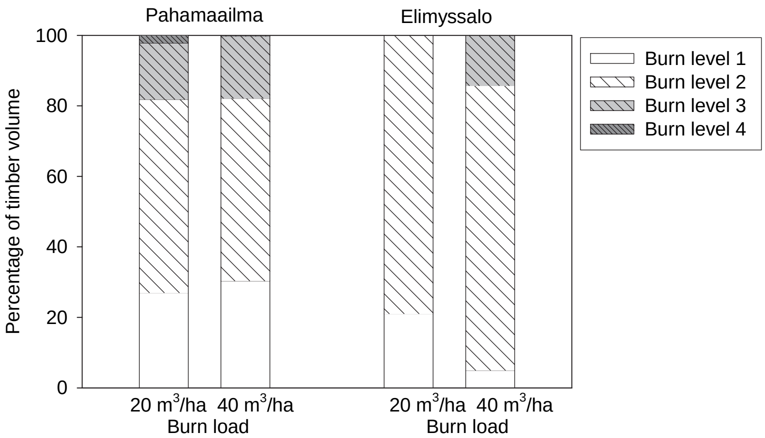

Figure 2. Percentage of timber volume classified to different burn level categories in two burn load treatments in Pahamaailma and Elimyssalo in 2006.

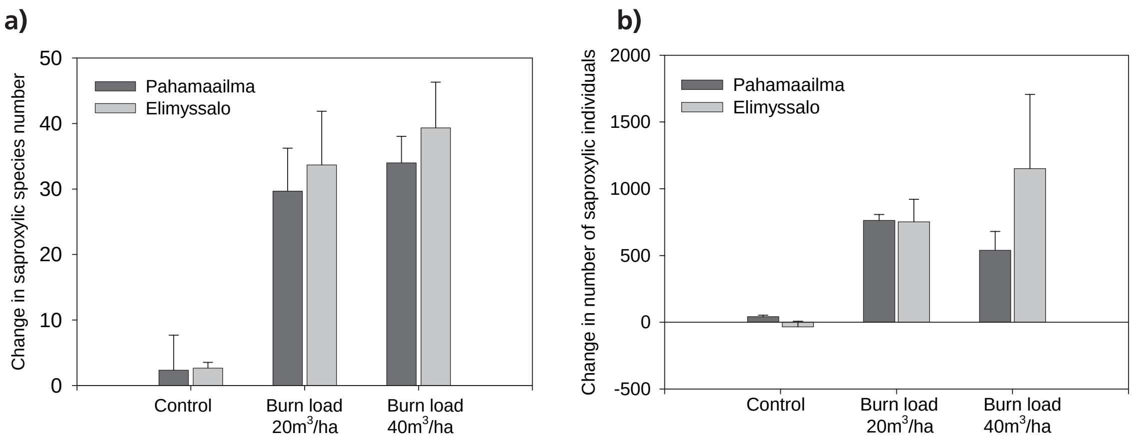

Figure 3. Change in the number of saproxylic beetle a) species and b) individuals in Pahamaailma and Elimyssalo in 2006 relative to the time before burning was applied.

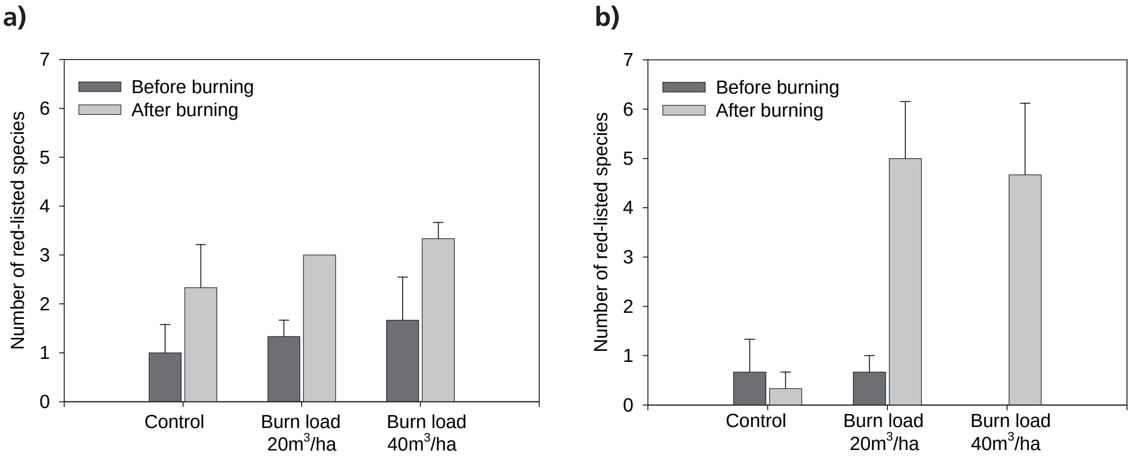

Figure 4. Number of red-listed species in a) Pahamaailma and b) Elimyssalo in control and burn load treatments.

The results show that prescribed fire of even a relatively low burn level has an immediate positive effect on the richness of saproxylic beetle species, when the burnings are conducted near source areas of beetle populations. The findings are in line with Hyvärinen et al. (2005), who show that the living conditions of saproxylic species can be enhanced by controlled burnings at least close to source areas of the target species. Burning of both young and relatively old forests had a positive effect on the richness of saproxylic beetles in our study. Suitable habitats for some endangered beetle species may therefore be maintained with regular prescribed fires of young and older forests in the Green Belt region, when trees are left at the burned sites.

Acknowledgements

We warmly thank Reijo Seppänen for managing the field measurements, Juha Siekkinen for incorporating the monitorings into the restoration plans, and Kari Kukko-oja for providing his wide expertise at the planning stage of the project. We also thank numerous people in Metla and our summer trainees for carrying out the tree stand structure measurements and for assistance related to beetle studies.

References

Hanski, I. 2000: Extinction debt and species credit in boreal forests: modelling the consequences of different approaches to biodiversity conservation. – Annales Zoologici Fennici 37: 271-280.

Horne, P., Koskela, T., Kuusinen, M., Otsamo, A. & Syrjänen, K. (eds.) 2006: METSOn jäljillä. Etelä-Suomen metsien monimuotoisuusohjelman tutkimusraportti. – Ministry of Agriculture and Forestry, Ministry of Environment, Finnish Forest Research Institute, Finnish Environment Institute, Helsinki. 387 pp.

Hyvärinen, E., Kouki, J., Martikainen, P. & Lappalainen, H. 2005: Short-term effects of controlled burning and green-tree retention on beetle (Coleoptera) assemblages in managed boreal forest. – Forest Ecology and Management 212: 315-332.

Kuuluvainen, T., Aapala, K., Ahlroth, P., Kuusinen, M., Lindholm, T. Sallantaus, T., Siitonen, J. & Tukia, H. 2002: Principles of ecological restoration of boreal forested ecosystems: Finland as an example. – Silva Fennica 36: 409-422.

Rassi, P., Alanen, A., Kanerva, T. & Mannerkoski, I. (eds) 2001: Suomen lajien uhanalaisuus 2000. – Ministry of Environment, Finnish Environment Institute, Helsinki. 432 pp.

Wikars, L.-O. 2002: Dependence of fire in wood-living insects: An experiment with burned and unburned spruce and birch logs. – Journal of Insect Conservation 6: 1-12.

Zackrisson, O. 1977: Influence of forest fires on the North Swedish boreal forest. – Oikos 29: 22-32.

11 Tree Regeneration after Fire

Michelle de Chantal

Finnish Forest Research Institute, Vantaa Research Unit, P.O. Box 18, 01310 Vantaa, Finland

During regeneration after natural or anthropogenic disturbances, the successful recruitment of new seedling cohorts often crucially depends on the availability of suitable microsites or "safe sites" (Harper et al. 1965, Simard et al. 1998). Although the diversity of microsites in managed forests in Finland is reduced compared to natural forests (Kuuluvainen & Laiho 2004), forest restoration treatments consisting of partial cutting with coarse woody debris creation and/or prescribed burning can increase microsite diversity (Lilja et al. 2007), and thereby have the potential to affect seedling abundance and distribution among microsites. The following results were obtained after restoration treatments in mature managed Norway spruce-dominated stands in upland and paludified biotopes in the Evo region, southern Finland. Restoration treatments consisted of four cutting treatments (Fig. 1): (1) uncut, (2) low-CWD (coarse woody debris), i.e., partial cutting leaving 50 m^3 ha^{-1} of standing retention trees and 5 m^3 ha^{-1} of down retention trees (drt) to create CWD, (3) intermediate-CWD, i.e., as previous but with 30 m^3 ha^{-1} of drt, and (4) high-CWD, i.e., as previous but with 60 m^3 ha^{-1} of drt. Half of the stands were burned, and half remained unburned.

Prior to treatments, seedlings of all studied species, i.e. Norway spruce, Silver and Hairy birches, and other deciduous (including Rowan, Aspen, Willow, and Alder), grew predominantly on level ground and mounds. Microsites on or next to a stump were also common in paludified biotopes, but in low numbers. Although there was up to 34.8 m^3/ha of CWD in stands prior to treatments, few seedlings were growing on or next to CWD, probably because it consisted mainly of small-diameter logging waste.

By itself, the cutting treatment did not change the seedling density of any species. In contrast, fire decreased the density of Norway spruce seedlings to almost zero in the upland biotopes (Table 1), mainly because it spread more evenly than in the paludified biotopes. On the other hand, the burning outcome was patchy in the paludified biotopes due to the wetness. As such,

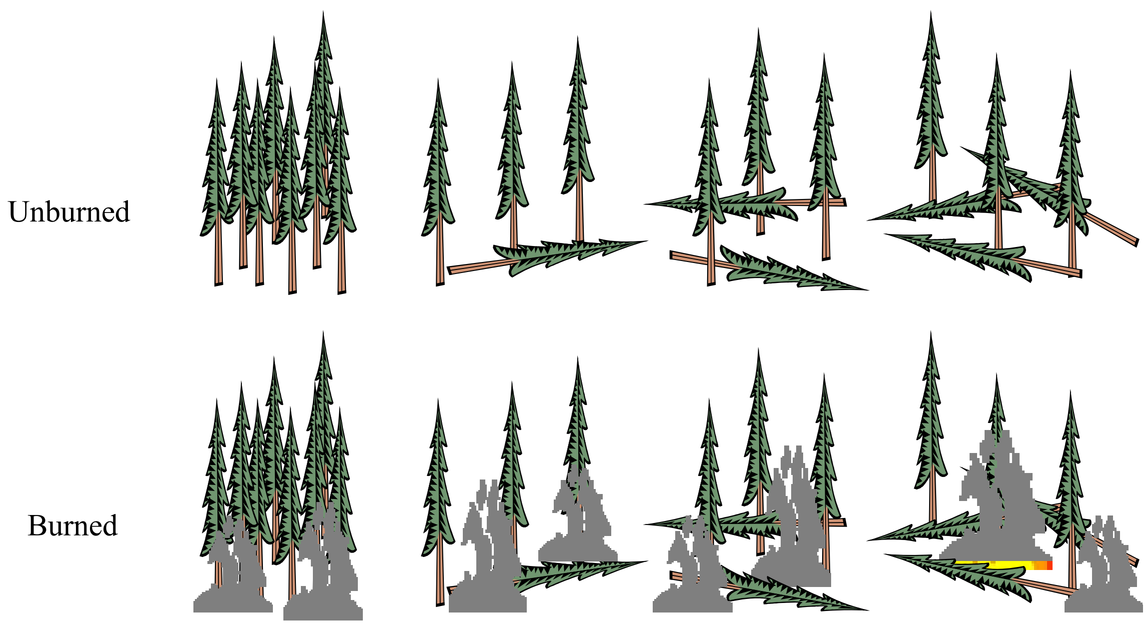

Figure 1. Illustration of the restoration treatments with the four levels of partial cutting with dead wood creation, with and without fire.

Table 1. Pre- and post-treatment seedling density (ha^{-1}) and standard error.

	Upland biotopes				Paludified biotopes			
	Pre-treatment		Post-treatment		Pre-treatment		Post-treatment	
	mean	std err.	mean	std err.	mean	std err.	mean	std err.
Unburned								
Uncut								
spruce	2125	1283	1375	617	17625	7250	9208	3759
birches	0	0	0	0	750	500	333	110
deciduous	4458	1980	3333	1001	2375	1125	2833	1037
Low-CWD								
spruce	4583	3667	5000	4206	5833	1158	5458	1417
birches	417	417	1708	758	1458	561	12417	3908
deciduous	1917	671	2042	758	3667	1064	6125	1305
Intermediate-CWD								
spruce	5188	3437	3333	1585	5042	1146	3875	1231
birches	125	125	3458	2842	708	522	1625	439
deciduous	3438	1438	3167	1300	2792	491	2583	507
High-CWD								
spruce	3417	712	2208	481	6458	1341	4542	1312
birches	3125	1665	1583	983	1125	331	5542	3949
deciduous	4875	1231	4042	1086	2542	1341	1375	804
Burned								
Uncut								
spruce	2667	1774	1333	712	9750	9000	9667	7619
birches	375	260	1333	686	1042	292	958	423
deciduous	3208	726	3000	1422	1917	655	2000	947
Low-CWD								
spruce	7500	3903	42	42	3208	1869	792	730
birches	1417	830	8125	6097	2125	1583	11167	5357
deciduous	1000	315	1250	439	4417	1568	2250	732
Intermediate-CWD								
spruce	8125	3514	0	0	9417	3908	4625	2940
birches	167	167	1083	417	4000	331	45042	15152
deciduous	2708	1590	458	182	875	439	917	583
High-CWD								
spruce	2750	629	42	42	4375	804	1167	1105
birches	167	110	875	696	708	273	8625	1134
deciduous	1708	481	875	289	2750	1003	1125	382

Note: n=3 stands, except for the following pre-treatment combinations: unburned uncut in paludified biotopes, unburned and burned intermediate-CWD in both biotopes where n=2, and burned uncut in both biotopes where n=1.

part of the pre-treatment spruce seedling cohort survived and was added to the post-treatment cohort. Fire also interacted with the cutting treatment to change the seedling density of Silver and Hairy birches in the paludified biotopes, such that regeneration increased most with low-CWD in unburned stands but with intermediate-CWD in burned stands, the increase in seedling density being several times higher after burning (Table 1). At the same time, the seedling density of birch species decreased in uncut stands in the paludified biotopes. The cutting treatment and fire did not affect the density of birch seedlings in the upland biotopes, or that of other deciduous species in both biotopes. In the uncut stands, the seedling density of all species generally remained high after fire in both biotopes as these stands did not burn well due to the lack of logging residues and fallen crowns as burning material.

After the restoration treatments, the density of spruce and other deciduous species on level ground and mounds usually decreased in both biotopes, whereas that of birches increased, most likely because birches regenerated very abundantly. The number of birches and other deciduous species also increased next to CWD and under a fallen crown. Despite the creation of CWD, few spruce seedlings grew on or next to CWD; however, the number of spruce seedlings growing under a fallen crown generally increased in unburned stands. Most of the post-treatment CWD in our study was decay stage 1, which is not a suitable substrate for regeneration. Colonisation of CWD by spruce seedlings generally takes place 20-60 years after treefall, when CWD has reached more advanced decay stages (Zielonka 2006). However, fresh CWD may act as shelters offering protection against browsing (Ripple & Larsen 2001, de Chantal & Granström 2007) and changes in microclimate (Harper et al. 1965, Kuuluvainen & Kalmari 2003, de Chantal et al. 2005).

A high proportion of seedlings of all species were either weak or dying. Damage to spruce seedlings by mechanical means or unidentified causes was common in unburned stands while damage by fungus was common in the paludified biotopes. Damage to birch seedlings was almost exclusively caused by insects, with minor damage by mammals in unburned stands. The most common cause of damage to other deciduous species was mammals followed by insects in unburned stands, while insects caused more damage than mammals in burned stands.

Evidence of protection against browsing offered by CWD is provided by another study (de Chantal & Granström 2007) that took place in a large area of old-growth mixed Scots pine and Norway spruce forest that burned in Tyresta National Park in central Sweden. In the year following the fire, an abundance of European aspen and Goat willow seedlings regenerated naturally. Four years later, all seedlings growing outside aggregations of dead wood formed by windthrow of fire-killed trees had been browsed repeatedly (mainly by ungulates) and the average height was 60 ± 9 cm for aspen and 54 ± 12 cm for willow (Fig. 2). Inside the aggregations, only 33% of the tallest seedlings had any evidence of browsing, and in most cases only from one episode. Average

Figure 2. Browsing history of aspen and willow seedlings growing in open areas and dead wood aggregations. Marks along the bars indicate the height at browsing episodes.

height for aspen inside aggregations was 153 ± 41 cm and for willow 167 ± 27 cm (Fig. 2).

For aspen regeneration from seed, substrate and shelter by CWD are both important in the early stages, as shown by a sowing experiment in the burned intermediate-CWD stands in the Evo restoration experiment (de Chantal et al. 2005). Sowing areas were delimited on burned organic matter and mineral soil substrates, in open areas and in the shelter of CWD, in both paludified and upland biotopes. Since aspen seeds require high moisture conditions for germination, seedling emergence was highest on mineral soil in the paludified biotopes (Fig. 3). However, due to flooding caused by snowmelt in the spring and a rainy second summer, fewer seedlings survived so that establishment after two growing seasons was lowest on this combination of biotope and substrate. Instead, establishment was highest on mineral soil in the upland biotopes, and intermediate on burned organic matter in the paludified biotopes. No seedlings established on burned organic matter in the upland biotopes, most likely because it was too dry (Fig. 3).

The shelter of CWD was both beneficial and detrimental to aspen seedling emergence and establishment. For example, on mineral soil in the upland biotopes, the shelter of CWD increased emergence but decreased establishment during the first growing season. Evaporation of soil moisture was probably reduced in the vicinity of CWD, which was beneficial to seedling emergence. However, seedlings may not have received enough light to survive, especially in places where the vegetation near CWD grew dense. On the other hand, on both substrates in the paludified biotopes, seedling emergence was lower in the shelter of CWD than in open areas, for reasons that are not clear, but a greater proportion of them survived on mineral soil. Seedlings were taller on mineral soil than on burned organic matter during the first growing season: 9.0 mm in upland biotopes and 6.4 mm in paludified biotopes compared to 2.1 mm on burned organic matter in paludified biotopes. After two growing season, there were no differences between substrates and biotopes, and the average height was 19.0 mm.

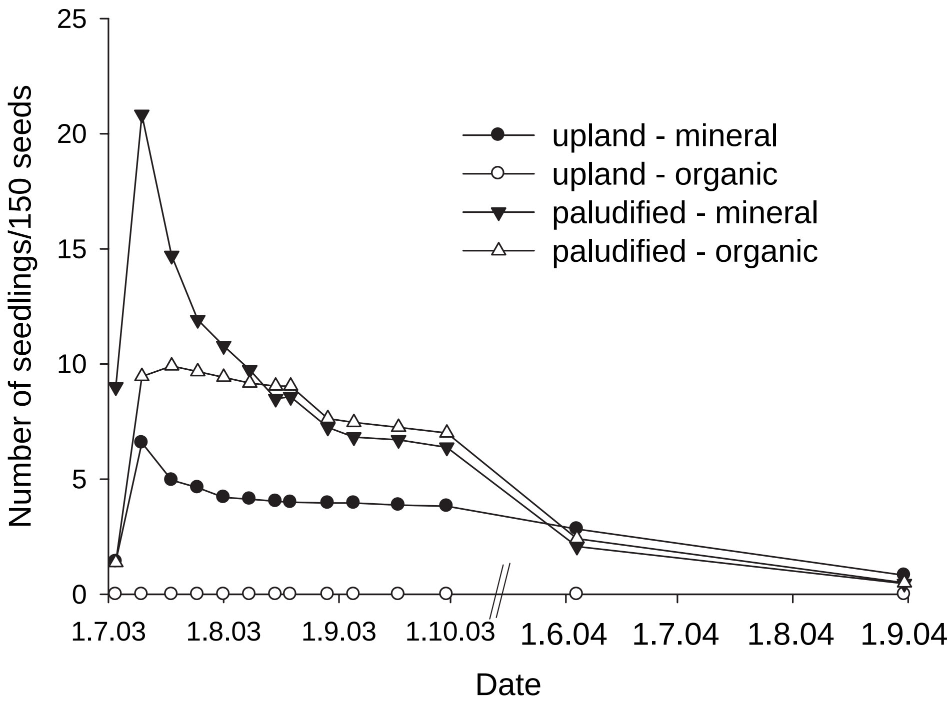

Figure 3. Number of living aspen seedlings during the first two growing seasons.

References

de Chantal, M. & Granström, A. 2007: Aggregations of dead wood after wildfire act as browsing refugia for seedlings of Populus tremula and Salix caprea. – Forest Ecology and Management 250(1-2): 3-8.

—, Kuuluvainen, T., Lindberg, H. & Vanha-Majamaa, I. 2005: Early regeneration of Populus tremula from seed after forest restoration with fire. – Scandinavian Journal of Forest Research 20(Suppl. 6): 33-42.

Harper, J. L., Williams, J. T. & Sagar, G. R. 1965: The behaviour of seeds in the soil I. The heterogeneity of soil surfaces and its role in determining the establishment of plants from seeds. – Journal of Ecology 53: 273-286.

Kuuluvainen, T. & Laiho, R. 2004: Long-term forest utilization can decrease forest floor microhabitat diversity: evidence from boreal Fennoscandia. – Canadian Journal of Forest Research 34: 303-309.

— & Kalmari, R. 2003: Regeneration microsites of Picea abies seedlings in a windthow area of a boreal old-growth forest in southern Finland. – Annales Botanici Fennici 40(6): 401-413.

Lilja, S., de Chantal, M., Peterson, C., Kuuluvainen, T., Vanha-Majamaa, I. & Puttonen, P. 2007: Microsites before and after restoration in managed Picea abies stands in southern Finland: effects of fire and partial cutting with dead wood creation. – Silva Fennica (accepted).

Ripple, W. J. & Larsen, E. J. 2001: The role of postfire coarse woody debris in aspen regeneration. – Western Journal of Applied Forestry 16(2): 61-64.

Simard, M. J., Bergeron, Y. & Sirois, L. 1998: Conifer seedling recruitment in a southeastern Canadian boreal forest: The importance of substrate. – Journal of Vegetation Science 9: 575-582.

Zielonka, T. 2006: When does dead wood turn into a substrate for spruce development? – Journal of Vegetation Science 17(6): 739-746.

12 The Research Base for Fire Management in Fennoscandian Forest Reserves

Anders Granström

Department of Forest Ecology and Management, Swedish University of Agricultural Sciences, 901 83 Umeå, Sweden
anders.granstrom@svek.slu.se

12.1 A slow move into action

At least since the late 1800s (Holmertz & Örtenblad 1886, Högbom 1906, Hesselman 1917) it has been generally accepted in the scientific community that fire has played a formative role for the European boreal forest. In Sweden, Kohh (1975) gave the first quantitative account of fire frequency. His study covers the last five hundred years in a district of northern Dalarna and nicely shows a relatively constant fire frequency throughout the period, until a sudden drop in the latter half of the 1800s. Similar results were obtained by Zackrisson (1977) 500 km further north. Nevertheless, it took the nature conservation authorities another 20-30 years to emulate this knowledge into forest reserve management (Granström 2001). The first fires were burned in a reserve-to-be in 1993 and from 2003 onwards the number of prescribed burns in forest reserves has increased sharply. While it is clear that substantial progress is being done today, there are still issues around fire management in boreal Fennoscandia where research would be helpful. Here I briefly discuss some of these.

12.2 Historic references

Management of forest reserves requires some notion of the desired future state. An intuitive idea is to use historic conditions as a reference (Fule et al. 1997). These can only be achieved through intensive spatiotemporal reconstructions, but surprisingly few such studies have been done in Fennoscandia. The published studies suggest rather sparse stands, frequently with as little as 100-200 larger pine trees per ha (Tirén 1937, Östlund & Lindersson 1995, Pahlén 2000). Relatively frequent fires would have kept surface fuels at low levels (Schimmel & Granström 1997), increasing the chances for sub-lethal fire intensity. Often the stand structure has been static over centuries (Fig. 1). Although this may have been the general picture, there is also evidence for stand-replacing events at smaller or larger scale, re-setting the stand development (Niklasson & Granström 2000).

Stand reconstructions are by necessity based on the presence of remnant trees and stumps and it is therefore difficult to avoid a bias in the sampling; It is only in areas with good material that

Figure 1. Over millions of hectares, the pre-industrial forest in Fennoscandia was pine-dominated and structurally complex. Often the stands were dominated by a sparse stratum of old pines that had survived repeated fires. However, this archetypical stand type is only one of several possible states. Picture: Anders Granström.

such efforts are undertaken (Fig. 2 and 3). For areas devoid of preserved material, past states are more open to speculation. This applies, not least, to spruce-dominated areas. Sometimes it may even be difficult to assess the past fire intervals, due to lack of material.

It is confirmed that stand-replacing fire has occurred in the past, but the frequency and spatial extent of such events is not known (Kuuluvainen 2002). Also, the post-fire stand development after high-intensity fire is poorly described for the European boreal forest. Clearly, dense deciduous stands can sometimes emerge after fire (De Chantal & Granström 2007), but their relation to soil type, fire behaviour variables etc is uncertain (Lampainen et al. 2004). Anyhow, stand-replacing fire would be difficult to emulate within the present structure of predominantly tiny forest reserves.

Figure 2. Pines with multiple fire scars testify to a regime of frequent low-intensity fires. Throughout Fennoscandia most of these trees were cut in the early period of large-scale logging. Often the stumps have also been removed for tar burning, making fire history work difficult. Photo: Anders Granström.

Figure 3. Remnant dead wood can make detailed reconstructions of stand structure and fire history possible. Photo: Anders Granström.

12.3 Cultural past

When planning for fire management the question of "naturalness" immediately comes to surface. If people were the cause of the majority of fires (Lehtonen & Kolstrom 2000, Wallenius et al. 2004), should we still try to manage nature reserves to emulate a largely human-driven fire regime? These questions deserve a thorough consideration, but in many regions the answer may be rather simple: with or without people, fire would have played a role. People have been present in the north throughout the Holocene, but it is clear that their cultural dependence on fire, and hence their use of fire, have shifted (Granström & Niklasson 2008). In interior northern Sweden there was a change in fire regime towards the late 1600s, early 1700s, associated with the shift towards a culture dependent mainly on cattle (Niklasson & Granström 2000). The number of fires per unit time and unit area went up several times, but the sizes went down. The net effect on fire frequency at point scale therefore was relatively small. Prior to the shift, fires per unit area and time were on par with the density of ignitions that lightning delivers today (i.e. an indication of a predominantly natural fire regime), but afterwards most fires were evidently of human origin. Such changes are likely to have occurred much earlier further south. Nevertheless, the effects of these changes on forest composition and stand structure are difficult to pinpoint and may have been rather small.

12.4 Technical problems

Reintroducing fire is not a problem-free business. The long fire-free periods (often 150-200 years for individual stands) can in itself have led to successional changes, but nearly always these are overshadowed by changes due to past cutting. The typical stands that today are being treated with prescribed fire are dramatically different from the pre-fire stands a few hundred years back and the fire effects can therefore be expected to differ too (Fig. 4). In some cases, fire alone will not do the job, but the key to successful "engineering" would be an intimate knowledge of fire behaviour and fire effects.

Fire intensity is the main fire variable controlling mortality (Fig. 5) in the tree canopy (Sidoroff et al. 2007). It is regulated by a number of factors which are by now well known (fuel structure, fuel moisture, wind etc (Tanskanen et al. 2007)). Depending on the site conditions on the burn day these have to be balanced by a careful handling of the ignition pattern. Depth of burn in the organic soil layers on the other hand, is determined mainly by the moisture content of the humus (Miyanishi 2001), and the chance of controlling soil impact is through selection of a proper burn day. Ecological consequences of variation in depth of burn are less easy to predict than those due to variation in fire intensity. One effect of deep burning, however, is root damage (Fig. 6), and such effects may be associated particularly with long fire-free periods. Here more research would be needed.

12.5 Conflicting interests

While most professional land managers today acknowledge the need for prescribed burning, still only few would extend it to all types of forest reserves. Spruce-dominated forests would rarely be considered, even when there is ample evidence of past fires. Here the discussion of forest continuity and late successional species become important (Gandhi et al. 2001, Norden & Appelqvist 2001). As more and more reserves are being brought into fire management, one can expect these latent management conflicts to surface. We know today that in Northern Fennoscandia, landscape-covering fires at scales upward of 50,000 ha occurred in the past (Niklasson & Granström 2000), and that permanently fire-free areas have been extremely rare (Hörnberg et al. 1995). If this also means there is little risk of loosing species due to prescribed fire in reserves, is uncertain at the moment. More has to be learnt on the habitat requirements and dispersal/colonizing capacity of late-successional organisms for a clear answer to that question.

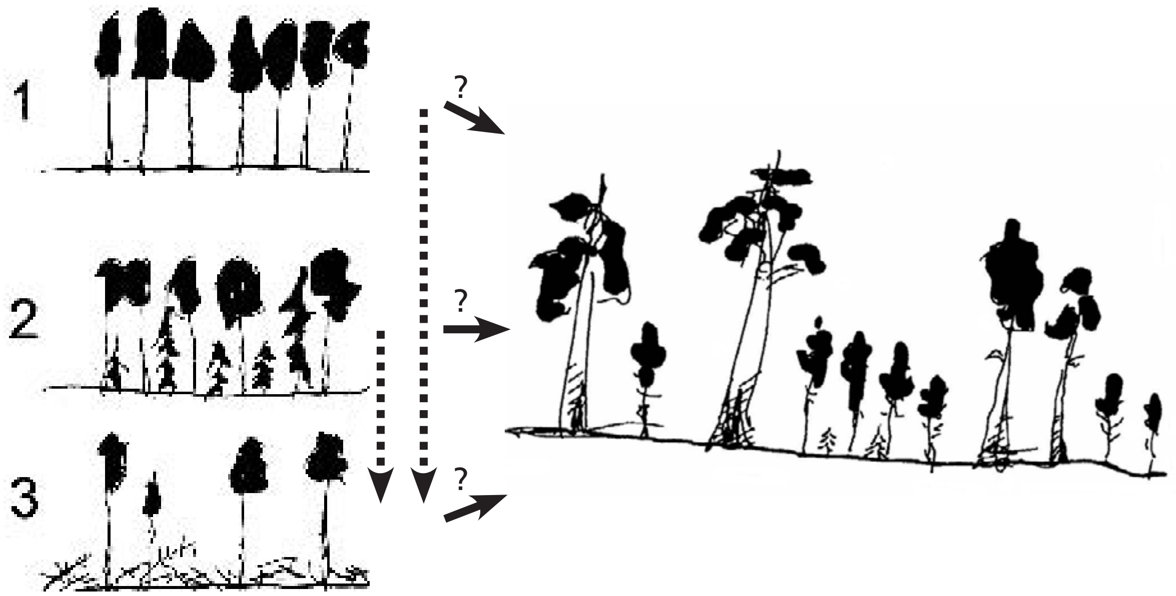

Figure 4. Schematic illustration of management challenges that typically arise when the long-term goal is to create a fire-structured multi-cohort pine forest. Often the starting point is a dense, uniform, pine-dominated stand (1), with little difference in tree diameter, and more importantly, in height. This results in little variation between trees in fire tolerance. Hence, the net outcome of burning is often either a complete stand kill, or no mortality at all. Another frequent starting point is a mixed conifer stand (2), with a dense undergrowth of spruce. Here, fire has the potential to select at the individual tree level, but the risk is that a high-intensity fire develops, due to the fuel structure of the stand. For both situation (1) and (2), a pre-fire cutting (3) can help create the desired goal. Any amount of cutting, however, will add to the surface fuels, making it difficult to keep fire intensity down, despite careful firing. Picture: Anders Granström.

Figure 5. Example of a pine-dominated stand that was subject to a pre-fire cutting, reducing the timber volume by 50%. The cutting was done in patches, to increase the structural variation at stand scale. The site was burned with a uniform ignition pattern (strip head firing with evenly spaced strips), to allow an evaluation of the effect of fuel variation on fire behaviour. The extra fuel in the cut patches resulted in higher fire intensity and increased canopy mortality downwind of the openings. The stand is part of a larger area, owned by one of the major Swedish forest companies, that will be permanently managed for conservation, i.e. with no timber extraction, but with repeated burning according to the past fire history. Photo: Anders Granström.

Figure 6. Fire during severe drought leads to deep burning in the humus layer and thus to severe root damage. These pines (upper panel) suffer reduced vitality, mainly as a consequence of root loss. The main roots are highly exposed to heat kill from smoldering fire (lower panel). Sampling revealed severe loss of both fine and coarse roots due to fire, but a surprisingly active regeneration of fine roots as evidenced by an in-growth study (Smirnova et al. 2008). Photos: Anders Granström.

References

De Chantal, M. & Granström, A. 2007: Aggregations of dead wood after wildfire act as browsing refugia for seedlings of Populus tremula and Salix caprea. – Forest Ecology and Management 250: 3-8.

Fule, P. Z., Covington, W. W. & Moore, M. M. 1997: Determining reference conditions for ecosystem management of Southwestern Ponderosa Pine. – Ecological Applications 7: 895-908.

Gandhi, K. J. K., Spence, J. R., Langor, D. W. & Morgantini, L. E. 2001: Fire residuals as habitat reserves for epigaeic beetles (Coleoptera: Carabidae and Staphylinidae). – Biological Conservation 102: 131-141.

Granström, A. 2001: Fire management for biodiversity in the European boreal forest. – Scandinavian Journal of Forest Research, supplement 3: 62-69.

Granström, A. & Niklasson, M. 2008: Potentials and limitations for human control over historic fire regimes in the boreal forest. – Philosophical Transactions of the Royal Society London B. doi:10.1098/rstb.2007.2205.

Hesselman, H. 1917: Om våra skogsföryngringsåtgärders inverkan på salpeterbildningen i marken och dess betydelse för barrskogens föryngring. – Meddelanden från statens skogsforskninginstitut 13-14: 923-1074.

Holmertz, C. G. & Örtenblad, T. 1886: Om Norrbottens skogar. – P. A. Norstedt & Söner, Stockholm. 120 pp.

Högbom, A. G. 1906: Norrland: Naturbeskrivning. – Almqvist & Wiksell. 412 pp.

Hörnberg, G., Ohlson, M. & Zackrisson, O. 1995: Stand dynamics, regeneration patterns and long-term continuity in boreal old-growth Picea abies swamp-forests. – Journal of Vegetation Science 6: 291-298.

Kohh, E. 1975: Studier över skogsbränder och skenhälla i älvdalsskogarna. [Summary: A study of fires and hard pan in the forests of Älvdalen]. – Sveriges Skogsvårdsförbunds Tidskrift 73: 299-336.

Kuuluvainen, T. 2002: Natural variability of forests as a reference for restoring and managing biological diversity in boreal Fennoscandia. – Silva Fennica 36: 97-125.

Lampainen, J., Kuuluvainen, T., Wallenius, T. H., Karjalainen, L. & Vanha-Majamaa, I. 2004: Long-term forest structure and regeneration after wildfire in Russian Karelia. – Journal of Vegetation Science 15: 245-256.

Lehtonen, H. & Kolstrom, T. 2000: Forest fire history in Viena Karelia, Russia. – Scandinavian Journal of Forest Research 15: 585-590.

Miyanishi, K. 2001: Duff consumption. – In: Johnson, E. & Sukunimi, M. K. (eds), Forest fires. Behavior and ecological effects. Academic Press, New York. Pp. 437-475.

Niklasson, M. & Granström, A. 2000: Numbers and sizes of fires: Long term spatially explicit fire history in a Swedish boreal landscape. – Ecology 81: 1484-1499.

Norden, B. & Appelqvist, T. 2001: Conceptual problems of ecological continuity and its bioindicators. – Biodiversity and Conservation 10: 779-791.

Pahlén, T. 2000: Att restaurera forna tiders beståndsstruktur. Ett exempel från Jämtgaveln. – Institutionen för skoglig vegetationsekologi, SLU, Umeå. 35 pp.

Schimmel, J. & Granström, A. 1997: Fuel succession and fire behaviour in the Swedish boreal forest. – Canadian Journal of Forest Research 27: 1207-1216.

Sidoroff, K., Kuuluvainen, T., Tanskanen, H. & Vanha-Majamaa, I. 2007; Tree mortality after low-intensity prescribed fires in managed Pinus sylvestris stands in southern Finland. – Scandinavian Journal of Forest Research 22: 2-12.

Smirnova, E., Bergeron, Y., Brais, S. & Granström, A. 2008: Postfire root distribution of Scots pine in relation to fire behaviour. – Canadian Journal of Forest Research 38: 353-362.

Tanskanen, H., Granstrom, A., Larjavaara, M. & Puttonen, P. 2007: Experimental fire behaviour in managed Pinus sylvestris and Picea abies stands of Finland. – International Journal of Wildland Fire 16: 414-425.

Tirén, L. 1937: Skogshistoriska studier i trakten av Degerfors i Västerbotten. – Meddelanden från Statens Skogsförsöksanstalt 30: 67-322.

Wallenius, T. H., Kuuluvainen, T. & Vanha-Majamaa, I. 2004: Fire history in relation to site type and vegetation in Vienansalo wilderness in eastern Fennoscandia, Russia. – Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 34: 1400-1409.

Östlund, L. & Lindersson, H. 1995: A dendrochronological study of the exploitation and transformation of a boreal forest stand. – Scandinavian Journal of Forest Research 10: 56-64.

Zackrisson, O. 1977: Influence of forest fires on the north Swedish boreal forest. – Oikos 29: 22-32.

13 The Prehistory of Prescribed Fires – an Archaeological View on Slash-and-burn Cultivation and Fire History

Tuija Kirkinen

University of Helsinki, Department of Archaeology. P.O. Box 59, 00014 University of Helsinki, Finland

13.1 Introduction

The prehistoric time was long considered as a phase with no importance in explaining and understanding modern landscapes (e.g. Foster et al. 2003). Especially in forested areas, the romantic idea of hunter-gatherers living in harmony with the surrounding primeval forests (Dincauze 2000, Briggs et al. 2006), as well as the concept of wilderness as an uninhabited and uncultivated area (e.g. Hallikainen 1998), have influenced on interpretations made by ecologists and archaeologists. However, the research has repeatably recorded human influence on areas long though of as pristine, and the beginning of anthropogenic impact on nature is now known to date back to the Stone Age (e.g. Smyntyna 2003).

In terrestrial biotopes, fire is considered to be the most important disturbance factor affecting biodiversity. Through millenniums, humans have used fire to modify their environments and, though, influenced the number, area and severity of fires. In archaeology, the anthropogenic use of fire is an essential object of archaeological research. During the last ten years, the archaeological investigations on long-term human use of fire have also been applied to restoration and conservation ecology (e.g. Foster et al. 2003, Hayashida 2005).

In this paper, the human impact on fire history is discussed from an archaeological point of view. First, a brief summary of archaeological and pollen analytical evidence of the prehistoric human use of fire in forested areas of eastern Finland is presented. Secondly, the use of archaeological methods on fire historical research is discussed. Finally, the importance of the archaeological research of fire layers is emphasized.

13.2 The long continuum of anthropogenic fires

Until the 20th century, fire is considered to have been the most important factor affecting the biodiversity of forests in the boreal zone (e.g. Zackrisson 1977, Wallenius 2004). The fire cycle, depending on the forest type as well as climatical, topographical, and hydrological factors, is estimated to range between 20-60 up to several hundreds or thousands of years (e.g. Pitkänen et al. 2002, Kotilainen 2004, Wallenius 2004). However, the human impact is discovered to increase the number of fires, although its effects on fire frequency and ecosystems in the long-term are still largely unknown (Lehtonen et al. 1996, Wallenius 2004).

The origins of human use of fire in Finland can be traced to the 9th millennium BC when the first pioneering stage of settling took place in the areas free from ice. From the archaeological evidence such as the remains of fireplaces, we know that fire was used at least for domestic purposes. The use of fire in prehistoric settlement sites can be presumed to have increased through time, as the new important innovations like the production of ceramics, bronze casting and the production of iron were all dependent on the use of fire. Besides these, fire was also used for ritual purposes, e.g. for cremation burials.

Almost from the introduction of fire, man has burned vegetation in order to create pastures for game and to improve foraging possibilities. This presupposed model of people-plant interaction is based on ethnographical and historical records supported by archaeological and palaeoecological data (e.g. Branch et al. 2005). In Finland, the marks of fires caused by Stone Age people are sparse. However, pollen analysis made in the vicinity of Stone Age dwelling sites e.g. in Taipalsaari, southeastern Finland as well as in Rääkkylä in eastern Finland, show increased frequencies of charcoal particles connected to species indicating the use of fire, low *Picea* frequencies and marks of deforestation. In Taipalsaari, the exceptionally high values of *Pteridium* about 6000-3700 cal BC are considered to indicate almost a continuous use of fire. (Vuorela & Kankainen 1993, Vuorela 1995, 1996a and cited literature, Vuorela 1996b). In addition to the controlled use of fire, hunter-gatherer populations are supposed to have caused forest fires accidentally. The possible evidence can be found in pollen analysis where the marks of nearby forest fires exist (Saastamoinen 1996). As the prehistoric dwelling sites were most typically situated on dry sandy soils, on *Pinus*-dominated or mixed forests, the areas suffered, at least, a moderate risk for forest fires.

The environmental effects, caused by the pre-agricultural populations, are supposed to be small-scale and local. To concretize this locality, in order to detect the Stone Age land-use by pollen analysis, the sampling site should be no more than 250 meters away from the dwelling site. If the radius grows, the signs of human impact are too weak to be recognized (Vuorela 1996a).

The increase in human impact on fire frequency is generally connected with agriculture and, especially, slash-and-burn cultivation (e.g. Renfrew & Bahn 1996). In Finland, the fire historical research has documented a remarkable shortening of fire cycle from the 16th-17th centuries onwards with contemporary data evidencing the beginning of continuous slash-and-burn cultivation (e.g. Lehtonen et al. 1996, Pitkänen et al. 1999, 2002). Although the significance of human influence on fire regime is evident during the Middle Ages and Modern Time, the preceding time can by no means be classified as lacking any anthropogenic burning. For example in eastern Finland, the beginning of the periodical signs of slash-and-burn cultivation date back to the end of the Stone Age and to the Early Metal Period (1800 BC-AD 300): e.g. Valkeala ca. 2200 cal. BC (Alenius et al. 2005), Puolanka ca. 2000 cal. BC (Vuorela & Kankainen 1991), Taipalsaari ca. 1400-1200 cal. BC (Vuorela 1995), and Outokumpu ca. 750 cal. BC (Saastamoinen 1996). Furthermore, the earliest signs of small-scale forest clearings connected with grazing coexisted and even preceded cultivation (Vuorela & Kankainen 1993, Saastamoinen 1996, Alenius et al. 2005, Alenius 2007). According to pollen analytical evidence, the beginning of continuous slash-and-burn cultivation can be dated in eastern Finland from the 5th century to the 16th-17th centuries (e. g. Vuorela & Kankainen 1993, Grönlund 1995, Alenius 2007). To conclude, it can be presumed that human land-use has influenced the fire cycle already during the Stone Age and especially during the Metal periods, although at a local level.

13.3 The archaeology of fire imprints on soils

In reconstructing the past human-environment relationship, the anthropogenic indicators on pollen analysis are interpreted in conjunction with archaeological evidence (see Dincauze 2000, Branch et al. 2005). As the use of fire is one of the first and the most significant ways in which people modified their environments, the impacts of fires, preserved in soils for centuries, are an essential object of archaeological research.

Fire usually – not always – leaves behind a visible layer of charcoal and ash which can be discovered archaeologically by excavating and by analyzing soil samples. As the carbonization improves the preservation of organic materials, the analyzing of charred seeds, wood fragments and other plant macrofossils can be used to study the vegetation burned, for example the forest structure and the possible marks of human impact on vegetation (e.g. Lindman 1991, Dincauze 2000, Lagerås & Bartholin 2003). These charcoal layers can be dated by radiocarbon dating, and, for more precise dates, by AMS (Accelerator Mass Spectrometry) radiocarbon dating.

By using archaeological methods, the aim is to differentiate the natural forest fires from anthropogenic ones. The most evident anthropogenic indicators consist of artifacts, e.g. ceramics, and structures like cairns connected to slash-and-burn cultivation. Furthermore, the structural modifications to natural layers e.g. by ploughing are typical to cultivated soils. On microscopic level, the soil micromorphological methods can be used to analyze the chemical, physical, and biological features caused by heat and fire, and to identify the anthropogenic features related to human activities (Courty 1992, Hayashida 2005 and cited literature).

The study of the anthropogenic use of fire has focused primarily on archaeological sites, where the imprints of fire are connected to numerous activities. In Nordic countries, although the interest in slash-and-burn cultivation has long traditions e.g. by historians (in Finland, e.g. Voionmaa 1947; Soininen 1974), the archaeological excavations on slash-and-burn fields and the question of anthropogenic fire layers were taken into consideration by archaeologists not until the 1990's (Lindman 1991, 1993, see also Larsson 1995 and Taavitsainen et al. 1998).

In Sweden, fire layers and especially prehistoric slash-and-burn fields and clearance cairns have been studied archaeologically for over 15 years (Gren 1997 and cited literature, Lagerås & Bartholin 2003 and cited literature). The pioneering research has been done by Gundela Lindman (1991, 1993, 1995). As an example, the results obtained by Lindman showed a site-level continuum of periodic slash-and-burn cultivation from the late Stone Age to the Middle Ages in Bohuslän, west coast of Sweden, and gave detailed information about the forest clearings, cultivation practices and grazing. During these 5000 years, the time intervals between burnings varied from 150 to 1000 years with no evidence of natural forest fires (Lindman 1993).

Internationally, the increasing interest in the long-lasting effects of past human land-use to biodiversity has raised the anthropogenic use of fire to the object of multidisciplinary research (e.g. the Long Term Ecological Research [LTER] program [see Foster et al. 2003 and cited literature]). During the past ten years, the archaeological evidence has been used to study the land-use legacies and, in co-operation with conservation biologists, exploited in restoration and conservation planning (e.g. Hayashida 2005).

In Finland, the study of fire history has not been central among archaeologists, with the exception of attention paid to slash-and-burn cultivation. The study of prehistoric slash-and-burn cultivation has been based mainly on pollen analytical evidence (e.g. Taavitsainen 1990, Taavitsainen et al. 1998, Grönlund 1995, Alenius 2007) while the excavations on slash-and-burn fields and clearance cairns are still few. However, in order to understand the cultivation practices and their long-lasting effects on environment, more detailed investigations including archaeological excavations, are needed. Also, the formation and morphology of anthropogenic fire layers, need to be studied (Fig. 1).

13. 4 Finally

The human use of fire has increased the number of fires in many different ways already during the prehistoric time. The anthropogenic burning has been studied mainly by using pollen and charcoal analysis and by dating the fire scars dendrochronologically. Past fires can also be studied archaeologically, as the burning leaves on soil traces which can be analyzed even after millenniums of years.

What archaeology can offer is the possibility to study fires that took place already during the prehistoric time. It also offers methodology to study fires *in situ*. And last but not least, it studies fires as a cultural phenomena, in other words, the human use of fire is always seen in a certain cultural and historical context.

In Finland, the signs of past fires are commonly seen in the soil profiles. These layers constitute evidence of the site-level land-use history from the Stone Age to the present day. For environmental archaeologists, the study of fire history could provide valuable information about the land-use history in forested areas poor in archaeological remains. For ecologists, the archaeological evidence could give new information about the millennium long traditions of slash-and-burn cultivation and forest grazing, as well as natural forest fires.

Figure 1. The reference material for the study of the formation and morphology of anthropogenic fire layers has been collected from Telkkämäki Nature Reserve, where the slash-and-burn cultivation has been (re)practiced from the 1990's in order to conserve traditional biotopes. Photo: Tuija Kirkinen.

References

Alenius, T. 2007: Environmental change and anthropogenic impact on lake sediments during the Holocene in the Finnish – Karelian inland area. – Ph.D. Thesis, Publications of the Department of Geology D11. <http://urn.fi/URN:ISBN:978-952-10-2615-7>, cited 1.12.2007

—, Saarnisto, M., Ojala, A. & Lavento, M. 2005: Repoveden kansallispuiston alueen sedimenttikerrostumat luonnon- ja maankäytön historian arkistona. – Geological Survey of Finland, unpublished report P 22.4.109. <http://arkisto.gsf.fi/p22/P22_4_109.pdf>, cited 1.12.2007

Branch, N., Canti, M., Clark, P. & Turney, C. 2005: Environmental archaeology. Theoretical and practical approaches. – Hodder Arnold, London. 240 pp.

Briggs, J., Spielmann, K., Schaafsma, H., Kintigh, K., Kruse, M., Morehouse, K. & Schollmeyer, K. 2006: Why ecology needs archaeologists and archaeology needs ecologists. – Frontiers in Ecology and the Environment 4(4): 180-188.

Courty, M.-A. 1992: Soil micromorphology in archaeology. – In: Pollard, A. M. (ed.), New developments in archaeological science. British Academy, Oxford. Pp. 39-59.

Dincauze, D. 2000:Environmental archaeology. Principles and practice. – Cambridge University Press, Cambridge. 587 pp.

Foster, D., Swanson, F., Aber, J., Burke, I., Brokaw, N., Tilman, D. & Knapp, A. 2003: The importance of land-use legacies to ecology and conservation. – BioScience 53(1): 77-88.

Gren, L. 1997: Fossil åkermark. Äldre tiders jordbruk – spåren i landskapet och de historiska sammanhangen. – Fornlämningar i Sverige 1. 2nd edition. – Riksantikvarieämbetet, Stockholm. 176 pp.

Grönlund, E. 1995: A palaeoecological study of land-use history in East Finland. – Ph.D. Thesis, Joensuun yliopiston luonnontieteellisiä julkaisuja 31. 74 pp.

Hallikainen, V. 1998: The Finnish wilderness experience. – Metsäntutkimuslaitoksen tiedonantoja 711. 288 pp.

Hayashida, F. 2005: Archaeology, ecological history, and conservation. – Annual Review of Anthropology 34: 43-65.

Kotilainen, M. 2004: Dune stratigraphy as an indicator of Holocene climatic change and human impact in Northern Lapland, Finland. – Ph.D. Thesis, Annales Academiae Scientiarum Fennicae Geologica-Geographica 166. <http://ethesis.helsinki.fi/julkaisut/mat/geolo/vk/kotilainen/dunestra.pdf>, cited 1.12.2007.

Lagerås, P. & Bartholin, T. 2003: Fire and stone clearance in Iron Age agriculture: new insights inferred from the analysis of terrestrial macroscopic charcoal in clearance cairns in Hamneda, southern Sweden. – Vegetation History and Archaeobotany 2003/12: 83-92.

Larsson, B. (ed.) 1995: Svedjebruk och röjningsbränning i Norden: terminologi, datering, metoder. – Nordiska museet, Stockholm. 190 pp.

Lehtonen, H., Huttunen, P. & Zetterberg, P. 1996: Influence of man on forest fire frequency in North Karelia, Finland, as evidenced by fire scars on Scots pines. – Annales Botanici Fennici 33: 257-263.

Lindman, G. 1991: Forntida svedjebruk: om möjligheterna att spåra forntidens svedjebruk. – Skrifter / Riksantikvarieämbetet, arkeologiska undersökningar 1. 47 pp.

— 1993: Svedjebruket i Munkeröd: ett exempel på periodiskt svedjebruk från yngre stenålder till medeltid i södra Bohusläns kustland. – Skrifter / Riksantikvarieämbetet, arkeologiska undersökningar 3. 164 pp.

— 1995: Forntida svedjeodling i Västsverige. – In: Larsson, B. (ed.), Svedjebruk och röjningsbränning i Norden: terminologi, datering, metoder. Nordiska museet, Stockholm. Pp. 51-63.

Pitkänen, A., Huttunen, P. Jungner, H. & Tolonen, K. 2002: A 10 000 year local forest fire history in a dry heath forest site in eastern Finland, reconstructed from charcoal layer records of a small mire. – Canandian Journal of Forest Research 32: 1875-1880.

—, Lehtonen, H. & Huttunen, P. 1999: Comparison of sedimentary microscopic charcoal particle records in a small lake with dendrochronological data: evidence for the local origin of microscopic charcoal produced by forest fires of low intensity of eastern Finland. – The Holocene 9(5): 559-567.

Renfrew, C. & Bahn, P. 1996: Archaeology: theories, methods and practice. – Thames and Hudson, London. 608 pp.

Saastamoinen, S. 1996: Prehistoric settlement in the Sätös area in Eastern Finland reflected in a pollen analysis made from the sediments of Lake Saari-Oskamo. – In: Kirkinen, T. (ed.), Pithouses and potmakers in Eastern Finland. Helsinki Papers in Archaeology 9: 119-134.

Smyntyna, O. 2003: The environmental approach to prehistoric studies: Consepts and theories. – History and Theory, Theme Issue 42: 44-59.

Soininen, A. 1974: Vanha maataloutemme. – Historiallisia tutkimuksia 96. 459 pp.

Taavitsainen, J.-P. 1990: Ancient hillforts of Finland: problems of analysis, chronology and interpretation with special reference to the hillfort of Kuhmoinen. – Suomen Muinaismuistoyhdistyksen Aikakauskirja 94. 294 pp.

—, Simola, H. & Grönlund, E. 1998: Cultivation history beyond the periphery: Early agriculture in the North European boreal forest. – Journal of World Prehistory 12(2): 199-253.

Voionmaa, V. 1947: Hämäläinen eräkausi. – WSOY, Porvoo. 537 pp.

Vuorela, I. 1995: Pollen evidence of Stone Age and Early Metal Age settlement in Taipalsaari, Southern Karelia, eastern Finland. – Fennoscandia archaeologica XII: 207-214.

— 1996a: Palaeoecological evidence of the Stone Age settlements of Pörrinmökki and Sätös, eastern Finland. Concluding report. – In: Kirkinen, T. (ed.), Pithouses and potmakers in Eastern Finland. Helsinki Papers in Archaeology 9: 135-147.

— 1996b: Palynological indication of the Stone Age dwelling site of Pörrinmökki, Rääkkylä, Eastern Finland. Environmental Studies is Eastern Finland. – In: Kirkinen, T. (ed.), Helsinki Papers in Archaeology 8: 129-142.

— & Kankainen, T. 1991:Siitepölyanalyyttinen tutkimus asutuksen vaikutuksesta kasvillisuuteen Puolangan kunnan Kotilan kylässä. – Geological Survey of Finland, unpublished report P 34.4.100. 21 pp.

— & Kankainen, T. 1993: Luonnon- ja kulttuurimaiseman kehitys Taipalsaaressa. – Geological Survey of Finland, unpublished report P 34.4.107. 46 pp.

Wallenius, T. 2004: Fire histories and tree ages in unmanaged boreal forests in Eastern Fennoscandia and Onega Peninsula. – Ph.D. Thesis, University of Helsinki, Department of Biological and Environmental Sciences & Department of Forest Ecology. <http://ethesis.helsinki.fi/julkaisut/bio/bioja/vk/wallenius/firehist.pdf>, cited 1.12.2007.

Zackrisson, O. 1977: Influence of forest fires on the North Swedish boreal forest. – Oikos 29(1): 22-32.

14 Prescribed Fires in a Landscape Context: Their Potential in Sustainable Forest Management Planning

Pasi Reunanen

University of Jyväskylä, Department of biological and environmental sciences, P.O. BOX 35, 40014 University of Jyväskylä, Finland

14.1 Introduction

The objective of sustainable forest management is to maintain ecological processes and support biological diversity in silviculture. This requires that sustainable forest management adapts characteristics from natural patterns and processes and implement them in an appropriate manner into silvicultural practises. The present management disturbance regime, however, varies in many respects from a natural disturbance regime. This is mainly because of two reasons. First, we are perhaps never able to mimic natural processes as such in modern forest management. Second, despite of vast research literature we still know relatively little about natural fire behaviour in a boreal ecosystem and the role of anthropogenic forest fires in Fennoscandia (e.g. Wallenius 2004). Nonetheless, prescribed fires or controlled burning has been applied traditionally in forest management and it has become an accepted management method in sustainable forestry.

14.2 Background

Even though large and often catastrophic field fires are fairly common in many forested ecosystems there seems to be a shortage of forest fires in Finland. Forest fire statistics show that large forest fires have been very rare in Finland during the last decades (Table 1).

However, smaller forest fires are common in Finland and there occur numerous tiny fires annually. These forest fires burn about 600 ha per year. The average size of a burned area is less than 1 ha (Finnish statistical yearbook of forestry 2006, Fig. 1). Small fires are rather evenly distributed across Finland and forestry centres. Most of these fires, however, are likely to be antropogenic.

It is obvious that forest fires used to be typical events in a boreal forest ecosystem (Kuuluvainen 2002, Ryan 2002). Regional disturbance regime (and especially fire) largely determined the dynamic characteristics of a boreal forest landscape. It is very essential to realise that regional disturbance regime affects many spatial structures in a boreal forest landscape and changes in spatial structures has temporal, often long-term effects on ecological processes. Fire disturbance always changes stand structure and, thus destroys habitat of some species at a stand scale, but at the same time disturbance event establishes new habitat for some other species. Large fire events affect local, even regional landscape structure. Broader-scale disturbances alter local habitat composition and may affect habitat networks. Regarding ecologi-

Table 1. Largest recorded forest fires in Finland during the recent decades.

Year of forest fire	Municipality	Estimated size of fire (~ha)
1959	Isojoki, Honkajoki	1,700
1960	Tuntsa	20,000
1970	Kalajoki	1,600
1970	Liminka	500
1992	Lieksa	150
1997	Laihia	150
1997	Tammela	250

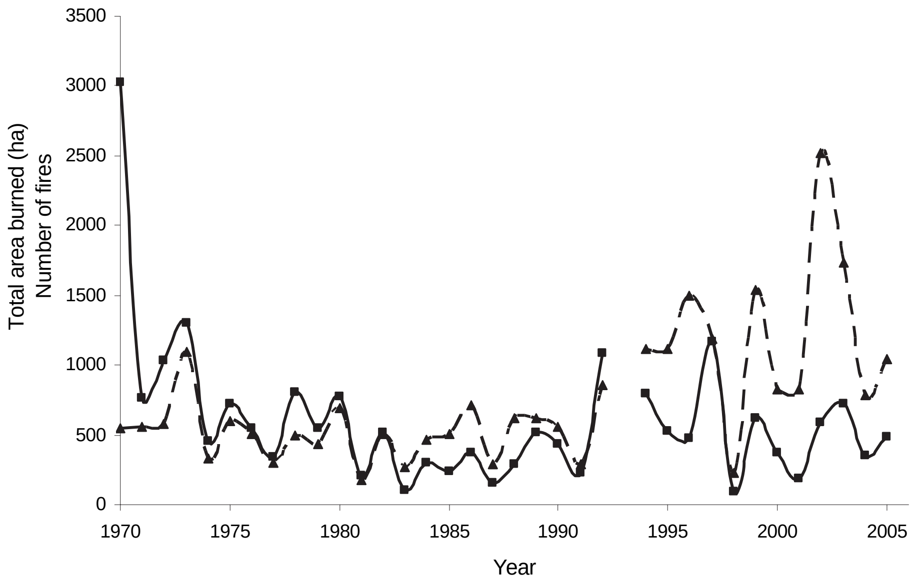

Figure 1. Forest fires in Finland 1970-2005. Squares denote the total annual area burned and triangles number of fires, respectively. Source: Finnish statistical yearbook of forestry 2006.

cal processes, fire events are normally linked with succession in vegetation, but disturbances also affect local and regional processes in populations of many organisms. Local population dynamics in some species may change dramatically at a burned site, whereas the same fire may contribute to the regional population dynamics of other species.

14.3 Spatial fire behaviour studies and simulation of fire regimes

Empirical fire history studies are ideally conducted in an unmanaged forest area where a systematic sample of forest sites over the entire area can be examined in the field. At these sites, signs of past fire events are investigated. Presence of charred organic matter in a forest floor and peat deposits are long-lasting signs of fire occurrence, but these observations cannot be used to date and locate a fire precisely. Therefore, fire studies are often based on fire scars in live and dead trees. From these data, one can count fire intervals but also assess fire severity. At best, observations from sample sites can be interpolated to obtain fire size estimates (e.g. Lehtonen 1997). In practise, many fire behaviour studies in Finland have been carried out in forest areas that have been selectively cut or partly managed in the past. In these forests the presence of old enough tree individuals is crucial. If fire scars cannot be found fire events can be assessed indirectly by inspecting tree age or diameter distributions.

Research of complex and dynamic spatial systems, such as forest dynamics in a boreal ecosystem, is carried out using adequate simulation tools (see Pennanen 2002). Simulation approaches of regional disturbance regimes are based on empirical studies and parameterisation of simulation models bases on quantitative observations on factors that are related to fires. However, depending on what factors are emphasized simulation approaches can be very different. In spatial fire dynamics, two simulation approaches can be roughly distinguished. Bottom-up approach starts from attributes that are relevant to fire ignition at a forest site (e.g. stand type and age, weather, fuel load), whereas top-down approach is based on fire consequences (fire frequency, size and severity). The aim of the study will decide which approach is favoured. The dividing element between the two approaches is how conditions for fire ignition are incorporated into a simulation. Top-down approach does not depend on site specific factors, whereas in bottom-up approach fire frequencies and sizes are emergent. Nevertheless, approaches described here are often somewhat overlapping.

Spatial simulation of fire regimes cannot avoid uncertainties in empirical data. In empirical studies discovery of small fires and light surface fires is dependent on spatial sample site density and these fire events may pass unnoticed. Fire sizes are interpolated over unsampled areas using logical decision rules such as natural fire breaks between forest and mire edges, streams and lakes (Lehtonen 1997) or simply by assessing distances between adjacent sample sites where fire was recorded during the same year (Niklasson & Granströn 2000). In empirical studies we observe consequences of fire but causes of ignition remain obscure because these factors cannot be assessed reliably afterwards. Reconstruction of the past fire environment i.e. fuel load at the site during ignition (total biomass on the site, quantity and arrangement of live and dead trees, woody debris, litter and humus) and weather conditions (relative humidity, wind conditions and drought) remain largely unknown. However, terrain (topography, slope angle, aspect and elevation) stays unchanged through times.

Observed patterns in fire history studies provide us one representation of a temporal sequence of disturbance events in a given landscape only. Fire behaviour depends on many dependent and independent factors that are stochastic, therefore observed empirical pattern is one stochastic pattern out of many alternative outcomes of complex stochastic processes. We may assume that the observed pattern represents a typical or an average pattern, but we have no tools to verify this assumption. To consider data uncertainties in spatial simulation study is essential. However, even though data uncertainties cannot be eliminated in simulations the effect and sensitivity of uncertain variables can be estimated using spatio-temporal simulations.

14.4 Fire management for species diversity

Because the practical fire management planning is basically not a stochastic process and fire is used as a management tool it is often not necessary to model (natural) fire behaviour in plans. The goal of fire management planning is often to create and restore suitable sites for endangered species. However, when making management decisions one does not always know where species in concern are located in the planning area and, additionally the status of known locations may change in time. In this spatio-temporal planning situation, application of appropriate simulation tools could markedly benefit long-term fire management planning. Utilisation of spatio-temporal simulations in forest management planning precludes that the aim of the systematic use of prescribed fire is carefully identified first. Then spatio-temporal simulations can be effectively applied to develop and design a dynamic habitat network for species at broader scale.

In present day forest landscapes, natural forest fires have been replaced by controlled use of fire in forest management. Prescribed fires are generally used 1) to enhance forest regeneration, 2) to restore forest within nature reserves and 3) to increase habitat for biodiversity. These uses of fire in forest management are semi-independent and they have different spatial dimensions. New tree generations are established in a forest stand, forest restoration aims at changing succession paths in a reserve, whereas habitat management for biodiversity may have regional goals. If the objective of fire management is to sustain forest biodiversity and design functional ecological networks for species, we need to combine different fire management modes on private and public lands.

In general fire management favours two species groups: species that require burned woody material and species that depend on dead wood. These forest species vary ecologically from each other. Pyrophilous species favour warm and light environments often early successional stages, whereas most saproxylic species require decaying wood to persist (Hyvärinen 2006, Junninen 2007). From such species roughly 10% are listed endangered and 8% near threatened (Rassi et al. 2001). Species involved are mostly beetles, butterflies, other insects, polypores and vascular plants. The use of fire in forest management is well justified by the number of species in danger, but fire management is likely to benefit many other species as well. From ecological characteristics of the two species groups follow that fire management has to consider two spatial and temporal scales. Spatial scales are connected with the movement and dispersal of the species. Many species, especially pyrophilous species, colonise burned sites rapidly and they are thought to disperse long distances. On the contrary, many species that use decaying wood as a primary habitat (e.g. polypores and some beetles) have a limited dispersal range. Temporal scales refer to decaying rate of dead wood and, thus changes in post-fire habitat quality. Time window for burned material is a few years and during this time ground vegetation recovers after the fire treatment and the quality of burned substrate changes. Decay of dead wood depends on the tree species and site conditions and this process will take decades or even a century. The system of various species groups and several spatial and temporal scales is a practical spatio-temporal modelling problem that can be applied in sustainable forest management planning where also other management goals are incorporated.

The goal of spatial fire planning is first to find suitable and appropriate locations for fire management. Then, spatially relevant ecological scales are included into the plan to reveal potential sites that best contribute to the fire site network. Finally, this procedure is run in time to show the dynamic changes in a fire site network. It is important to realise that many forest sites contain quantities of dead wood independently of fire or fire management. These sites host many pyrophilous and saproxylic species and are, thus a part of the presented dynamic ecological network (Fig. 2).

In this approach, two different and partly overlapping dynamic networks are simulated simultaneously. In simulation, potential sites that are likely to be colonised from previous fire management sites are located. Forest sites that are managed with fire are only a subset of all potential forest sites for pyrophilous and saproxylic species. Therefore, fire management sites are, also, likely to enhance interactions among fire management sites and less suitable or even unsuitable sites where species may have survived temporally.

14.5 Conclusions

In this example approach, fire dynamics as such was not simulated, but a spatio-temporal simulation approach was applied to find relevant and appropriate locations for dynamic and long-term fire management. This approach enables the assessment of consequences of fire management plans because fire site network and alternative networks can be simulated in a real forest landscape context. Boreal forest landscapes are regionally markedly variable in natural pattern, therefore management strategies and goals need to be assessed also regarding the current landscape context in the planning area. Ecologically sustainable fire management plans must be based on recent knowledge of fire behaviour and population ecology of target species. The aim of fire management should not be the use of fire and structures that fire leaves behind but spatially functional populations and maintenance of ecological processes. Patterns that are developed in fire management must be linked with ecological processes that are dependent on them.

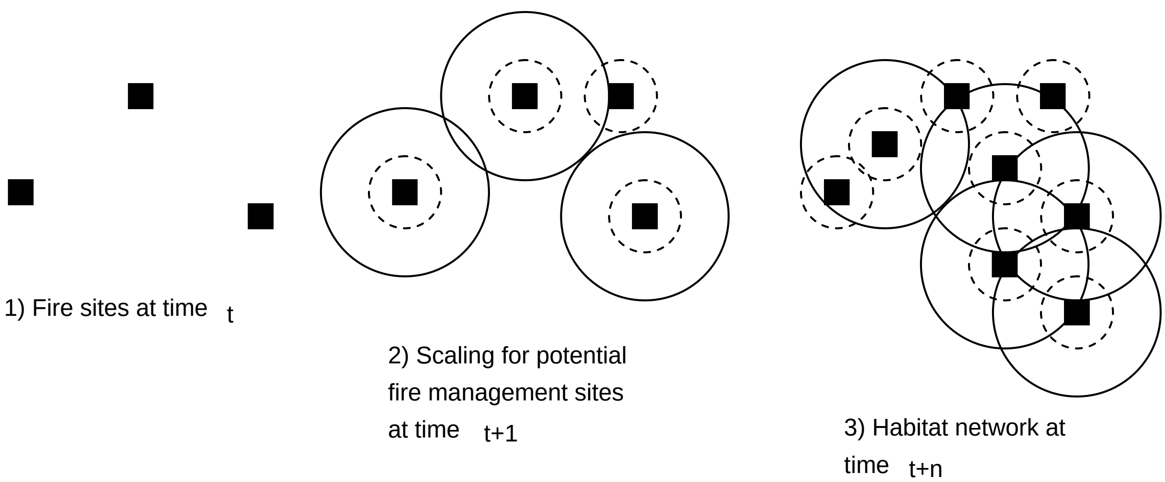

Figure 2. A schematic illustration of a systematic fire management planning procedure, where the goal is to design a functional, long-term ecological habitat network. Concentric circles denote spatial scales that are relevant to the management planning.

References

Finnish statistical yearbook of forestry 2006. – Metsäntutkimuslaitos, Vantaa. 416 pp.

Hyvärinen, E. 2006: Green-tree retention and controlled burning in restoration and conservation of beetle diversity in boreal forests. – Academic dissertation, University of Joensuu, Faculty of forestry, Joensuu. 55 pp.

Junninen, K. 2007: Conservation of polypore diversity in managed forests of boreal Fennoscandia. – Academic dissertation, University of Joensuu, Faculty of forestry, Joensuu. 32 pp.

Kuuluvainen, T. 2002: Disturbance dynamics in boreal forests: defining the ecological basis of restoration and management of biodiversity. – Silva Fennica 36: 5-12.

Lehtonen, H. 1997: Forest fire history in north Karelia: dentroecological approach. – University of Joensuu. Research notes 59: 1-23.

Niklasson, M. & Granström, A. 2000: Numbers and sizes of fires: Long-term spatially explicit fire history in a Swedish boreal landscape. – Ecology 81: 1484-1499.

Pennanen, J. 2002: Forest age distribution under mixed-severity fire regimes – a simulation-based analysis for middle boreal Fennoscandia. – Silva Fennica 36: 213-231.

Rassi, P., Alanen, A., Kanerva, T. & Mannerkoski, I. 2001: Suomen lajien uhanalaisuus 2000. – Ympäristöministeriö and Suomen ympäristökeskus, Helsinki. 432 pp.

Ryan, K. C. 2002: Dynamic interactions between forest structure and fire behaviour in boreal ecosystems. – Silva Fennica 36: 13-39.

Wallenius, T. 2004: Fire histories and tree ages in unmanaged boreal forests in Eastern Fennoscandia and Onega peninsula. – Academic dissertation, University of Helsinki, Faculty of Biosciences, Department of biological and environmental sciences and Department of forest ecology. 66 pp.

15 Distribution and Habitat Requirements of *Boros schneideri* in Ruunaa Natura 2000 Area

Tuuli Tikkamäki[1] and Maarit Similä[2]

[1] University of Joensuu, Faculty of Forest Sciences, PO Box 111, 80101 Joensuu, Finland
[2] Metsähallitus, Natural Heritage Services, Urheilukatu 3A, 81700 Lieksa, Finland

Saproxylic species constitute a significant proportion of the threatened species in Finland. They suffer from the lack of natural forest structures – especially from the lack of dead wood – and processes in a managed forest landscape. *Boros schneideri* (Coleoptera: Boridae) is a saproxylic beetle species listed in Annex II of council directive of the European Union and it is classified as threatened species in Finland (IUCN class Vulnerable). *Boros schneideri* requires dead, bark-covered standing pines for habitat and substrate. Under the bark it feeds on dark fungal growth. Such habitat is suitable for *B. schneideri* only for a few years in the same tree and that is why there must be continuous supply of dying pine trees in a stand and landcape scale in order the species to persist.

Boros schneideri is known to occur mainly in eastern Finland. There are very old observations also from southern Finland and more recent from central Finland and Lapland. The existence of other than the most eastern populations seems uncertain. *B. schneideri* is known to occur in Ruunaa Natura 2000 area. More detailed information was collected about the species' habitat requirements and distribution within the protected area during 2007. This is crucial background information for the species' monitoring in restored forest stands in Ruunaa.

Restoration of pine forests in Ruunaa started in 2005 as a part of the Life Nature project "Restoration of boreal forests and forest covered mires" (Metsä-Life). Dead wood was created in several stands and one 8 ha stand was also burnt.

Habitat requirements of *Boros schneideri* were surveyed by debarking suitable trees up till 1.6 meters height. The number of debarked trees was circa 450 of which 150 situated in Patvinsuo and 300 in Ruunaa. In total, 17 inhabited trees were observed. They mainly situated in stands with trees over 100 years old. Also the amount of dead standing and fallen trees was high around inhabited trees. The trees occupied by the species were on average 22 cm (14-31) by diameter[1.3] and the average age was 122 years (53-200). It seems that *B. schneideri* favours old but not necessarily very thick trees and is very dependent of the landscape level continuum of dead trees.

In the present mapping, *B. schneideri* larvae were found from one fallen dead tree which situated in the small restoration gap. Larvae have been found earlier from stumps in burned areas. Restoration of forests – including the production of dead wood and burning of the forests – could help the species especially in areas without natural forests characteristics.

16 Effects of Prescribed Burning on Saproxylic Beetles in the Green Belt of Finland

Anne-Maarit Hekkala & Anne Tolvanen

Finnish Forest Research Institute, Muhos Research Unit, Kirkkosaarentie 7, 91500 Muhos, Finland

The Green Belt is an extensive network of old-growth forests, aapamires, boreal hills and arctic fells on the border of Finland, Russia and Norway. In order to improve the conservation status of some protected Natura 2000 areas, Metsähallitus has carried out restoration practices in the Green Belt of Finland during 2004-2008. The Finnish Forest Research Institute has been studying the effects of restoration on forest-dwelling species assemblages since 2005. The purpose of this study is to investigate how different restoration practices work to re-establish forests to their original state and function, and how different forest-dwelling species respond to these restoration practices.

This study design includes nine pine-dominated study sites in both Pahamaailma and Elimyssalo in eastern Finland with two burn treatments and untreated control. In one burn treatment 20 m^3/ha of living pines were felled before burning and in the other burn treatment the amount of felled trees was doubled. Beetles were collected with six window traps in each study site from mid-May to mid-September in 2005 and 2006. Prescribed burns were conducted in late June 2006. Altogether 29,044 beetle individuals were identified into 394 species. Difficult staphylinids and *Atomarias* were not identified. Emphasis was placed on saproxylic (dead-wood-dependent) species.

In Pahamaailma the number of beetles doubled during the year of treatments and number of beetle species increased from 220 to 273. In Elimyssalo the number of individuals increased three-fold and number of species increased from 168 to 240. In both study areas the richness of saproxylic species increased during the year of burning at the burned sites, whereas richness even decreased at the unburned control sites. There were no clear differences in species richness between the two burn treatments immediately after burn, but the species assemblages were clearly different on burned sites compared to control sites according to NMS (nonmetric multidimensional scaling). Despite of differences in geographical region and forest age, the saproxylic beetle assemblages of Pahamaailma and Elimyssalo were close to each other after burns. The richness of red-listed (incl. NT, VU, EN) species significantly increased on burned sites after fire. Altogether 13 red-listed species (313 ind.) were caught only from burned study sites.

The results show that prescribed burns have a positive effect on saproxylic beetle species richness. Also endangered beetle species benefit by controlled burning, although some species might disappear following fire application. In the vicinity of adequate source areas, suitable habitats for some endangered fire-dependent beetle species assemblages can be maintained with prescribed burnings, where the trees are left on the burned sites after fire.

17 Increasing the Amount of Dead Aspen in a Conservation Area: Colonisation of Transported Logs by Aspen-specialists

Petri Martikainen

Faculty of Forest Sciences, University of Joensuu, P.O.Box 111, 80101 Joensuu, Finland

Introduction

Scarcity of dead wood is a major problem in many protected forest areas today. Especially the continuity of certain dead-wood qualities such as recently dead aspen (*Populus tremula*) may be in danger, increasing the risk of local extinctions of threatened specialist species. One possibility to relieve the lack of dead wood is to purchase fresh logs from managed forests and to transport them to the conservation area.

The experiment

The applicability of this method was tested in Kakonsalo Natura 2000 area in Savonranta, eastern Finland. This locality is famous for the numerous threatened aspen-specialists occurring in the area. Altogether 348 fresh, healthy aspen logs were transported to the area in February 2005. The logs were placed in 58 piles along forest roads, with varying distance to two aspen-rich core areas, Raatelamminsalo and Muhamäki. Each pile contained 6 logs, one of which was set up in a vertical position.

Monitoring of colonisation

Beetles (Coleoptera) and flat bugs (*Aradus* and *Aneurus* spp.; Heteroptera) colonising the logs were monitored using trunk-window traps. One trap was attached to the standing log in each of the piles. The surveying has lasted now three seasons (2005-2007) and preliminary results are available for one sampling period (10.5.-14.6.2006). In addition, characteristic exit holes of aspen-specialist beetles *Xylotrechus rusticus* and *Trypophloeus* spp. (mainly *Trypophloeus bispinulus*) were inspected from the logs on 14th August 2007.

Results

Trunk-window traps

Altogether 4,830 beetles and flat bugs were caught in the traps during 10.5.-14.6.2006. The samples were selectively identified to reveal most of the aspen specialist and red-listed species. In both these groups the number of species caught per pile was independent of the distance to the core areas (Fig. 1). Nine red-listed species were

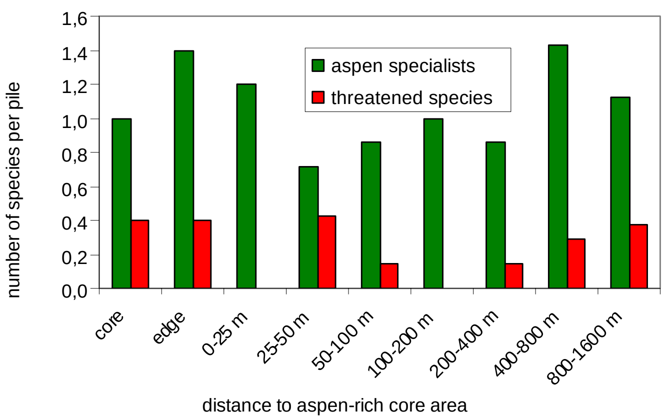

Fig. 1. Number of aspen-specialist and red-listed species per trap (=log pile) at different distance classes from the aspen-rich core areas.

caught in the traps, all of which can potentially utilize aspen logs at some phase of the decay process (Table 1). Three of the species were new to the area: *Aneurus avenius*, *Scotodes annulatus* and *Trypophloeus discedens*.

Exit holes

Altogether 666 exit holes of *Xylotrechus rusticus* and 685 exit holes of *Trypophloeus* spp. were recorded. Both species clearly favoured thick logs, *Xylotrechus rusticus* those laying in the upper layer of the pile, *Trypophloeus* spp. standing ones.

Table 1. Red-listed species caught in the trunk-window traps. Abbreviations: EN=Endangered, VU=Vulnerable, NT=Near Threatened.

Flat bugs (Heteroptera)	
Aradus truncatus	VU
Aneurus avenius	VU
Beetles (Coleoptera)	
Ampedus suecicus	NT
Cis micans	NT
Peltis grossa	NT
Scotodes annulatus	VU
Trypophloeus discedens	EN
Xylotrechus rusticus	NT
Zavaljus brunneus	VU

Conclusions

– Logs transported to the area were successfully located and colonised by many aspen-specialists and red-listed species.
– Transportation of aspen-logs, preferably thick ones, into a protected area can be a valuable tool in the conservation of threatened species.
– Many aspen specialists are able to efficiently disperse considerable distances, potentially more than 1,600 m from the source areas, as even the most distant log piles were colonised.

18 Increasing the Volume of Dead Wood: Effects on Saproxylic Beetles

Esko Hyvärinen[1] & Janne S. Kotiaho[2]

[1] Metsähallitus, Natural Heritage Services, Jyväskylä, Finland
[2] University of Jyväskylä, Department of Biological and Environmental Science, Jyväskylä, Finland

During the Forest Biodiversity Programme for Southern Finland, called the METSO Programme, Metsähallitus has designed and carried out restoration measures in certain parts of reserves to help habitats to revert towards their natural-like state. In order to evaluate the effectiveness of these measures monitoring site network has been established including 18 Scots pine (*Pinus sylvestris*) dominated and 13 Norway spruce (*Picea abies*) dominated sites. Most of the sites are also target sites of the Life project "Restoration of Boreal Forests and Forest-covered Mires". This paper presents the very first results of a survey, where effects of increased volume of dead wood on saproxylic (deadwood dependent) beetles are monitored.

The restoration measures had been executed at the study sites during winters 2003-2006. The measures that had been used were girdling of pines and spruces and cutting them down. Also high stumps were left. The results shown here are based on beetle data collected by window flight traps from 7 pine-dominated and 6 spruce-dominated sites over the summer 2006. Each study site had three control and three experimental plots. At each study plot two traps were used to obtain representative samples.

The data include a total of 20,406 beetle individuals representing 592 species. Altogether 13,338 individuals of 276 saproxylic species were observed. Of these, 7,418 individuals and 239 species were found in pine-dominated sites (n=7) and 5,920 individuals of 204 species in spruce-dominated ones (n=6). The mean number of saproxylics was higher in study plots where volume of dead wood was increased than in control plots both in pine-dominated and in spruce-dominated sites.

The results presented here demonstrate the short-term effects of increasing the volume of dead wood on saproxylic beetles. Further monitoring is needed to reveal the longer-term effects and effects on different saproxylic organisms such as polypores. With these data it can be safely concluded, however, that increasing volume of dead wood is clearly beneficial for numbers of saproxylic beetle species.

ISSN 1235-6549
ISBN 978-952-446-630-1 (printed)
ISBN 978-952-446-631-8 (pdf)

Publications can be ordered from:
Julkaisua voi tilata osoitteella:

Metsähallitus
Customer services / Asiakaspalvelut
P.O. Box 36, FI-99801 Ivalo
FINLAND
e-mail: natureinfo@metsa.fi
www.metsa.fi

Telephone: +358 205 64 7702
Puhelin: 0205 64 7702

NORDIC ENVIRONMENTAL LABEL
441 002
Printed matter

Edita Prima Oy, Helsinki 2008